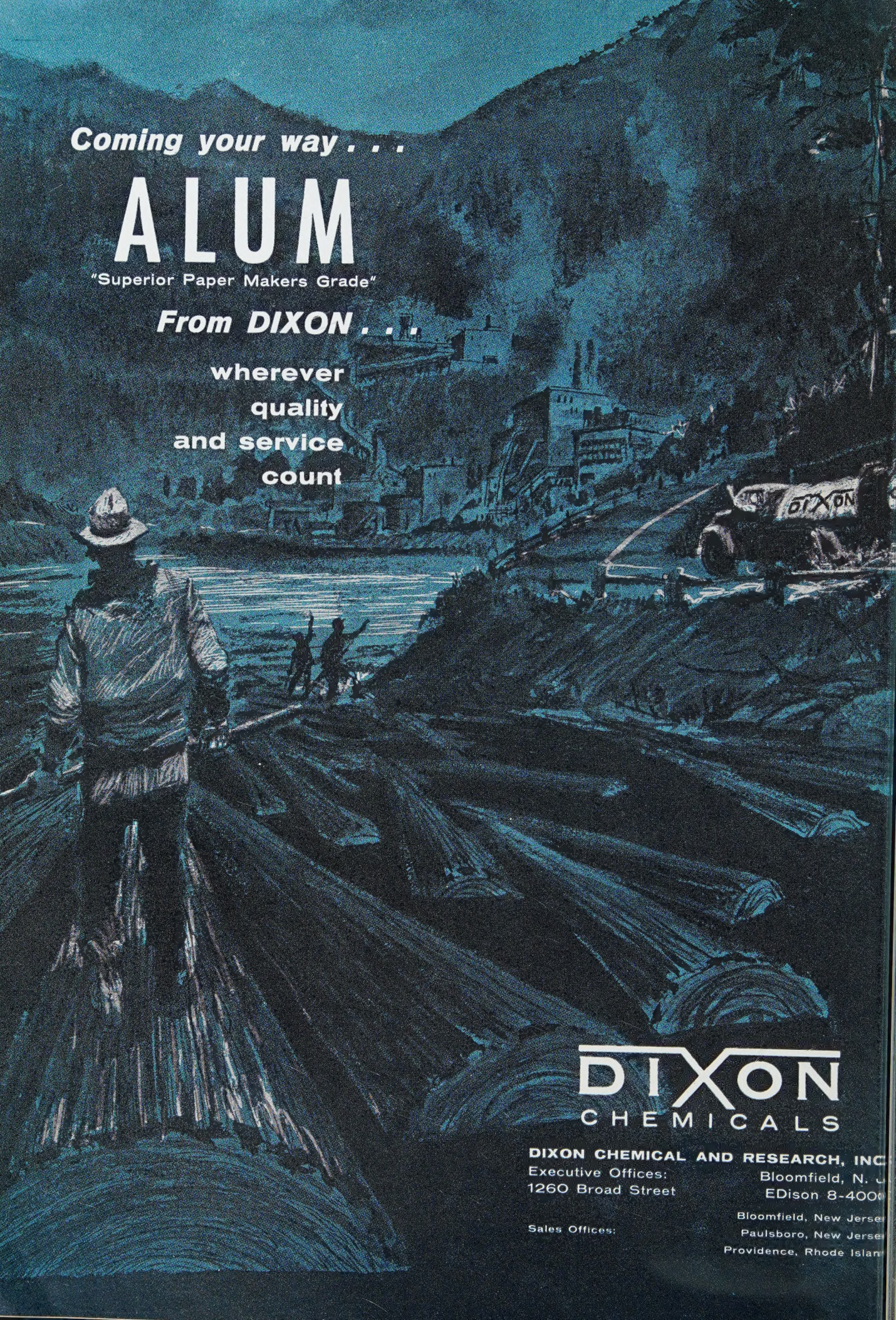
# Tappi

JOURNAL OF THE TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY

JUNE 1960

VOLUME 43 • NUMBER 6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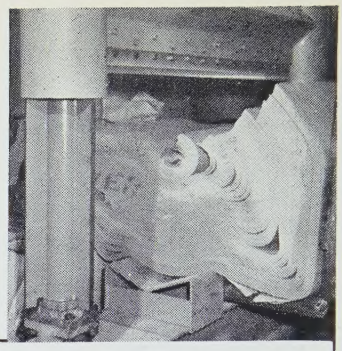

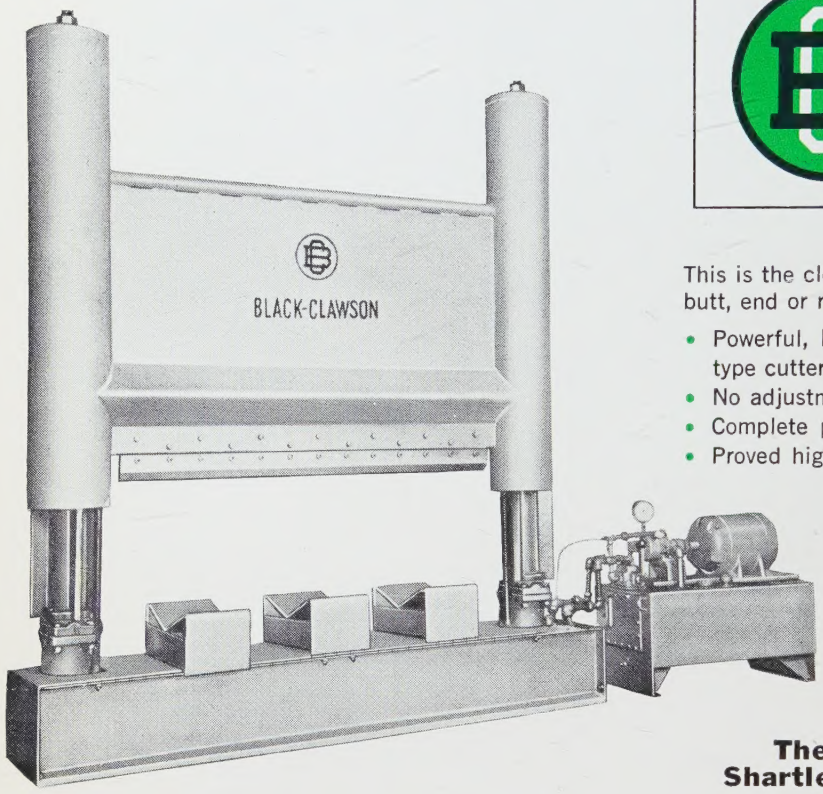


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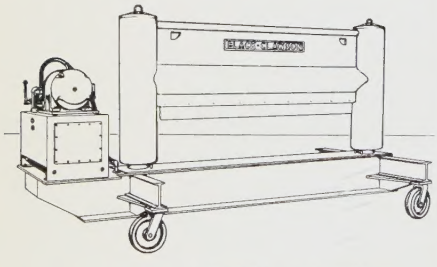

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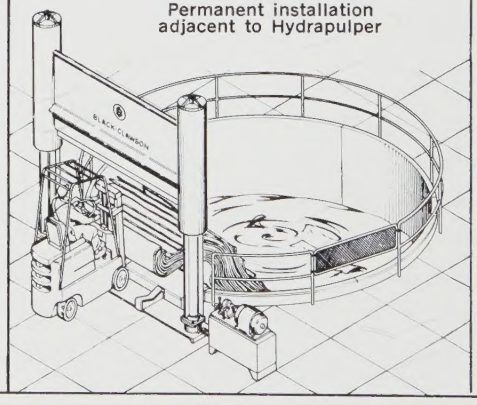

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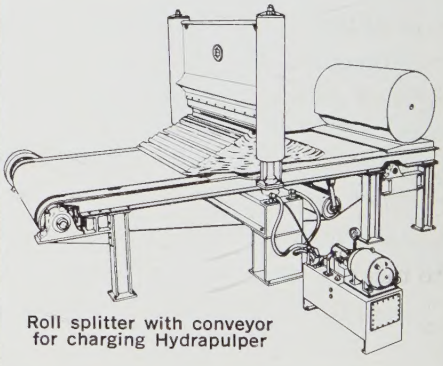

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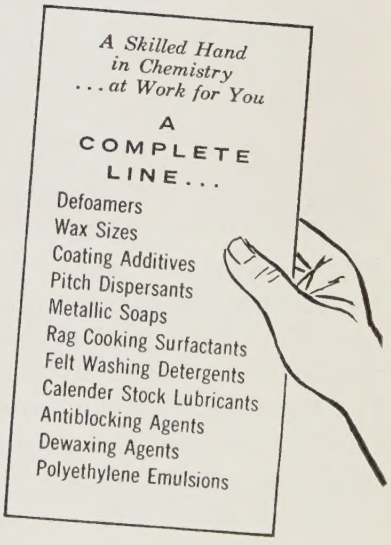


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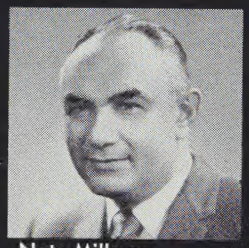

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Forest Biology Conference
Seattle, Wash.
Aug. 24–27, 1960.

Eleventh Testing Conference
Pantlind Hotel, Grand Rapids, Mich.
Sept. 27–29, 1960.

Tenth Corrugated Containers Conference
Royal York Hotel, Toronto, Canada
Oct. 10–13, 1960.

Fifteenth Plastics-Paper Conference
Hotel Syracuse, Syracuse, N. Y.
Oct. 17–19, 1960.

Fifteenth Engineering Conference
Robert Meyer Hotel, Jacksonville, Fla.
Oct. 24–28, 1960.

**Please refer to Local Section Activities for the locations and dates of Section meetings**

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**No. 65 — Peroxide Bleaching of Southern Pulps.**

**No. 66 — Becco Laboratory Procedures for Pulp Bleaching, 1955 Ed.**

**No. 91 — Peroxide Bleaching of Chemi-Mechanical Hardwood Pulps.**

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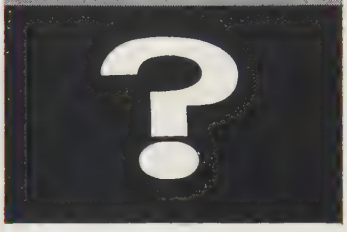


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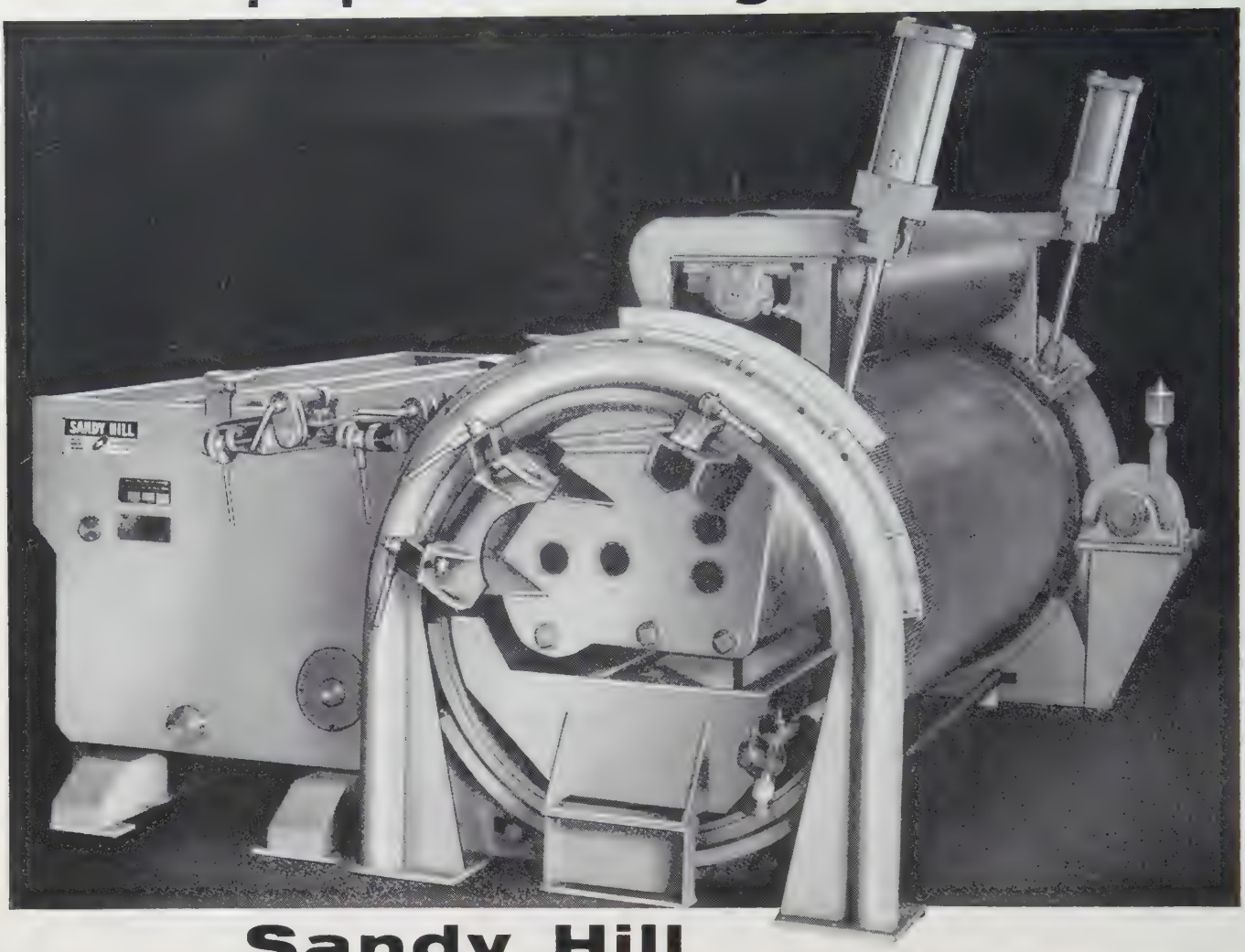


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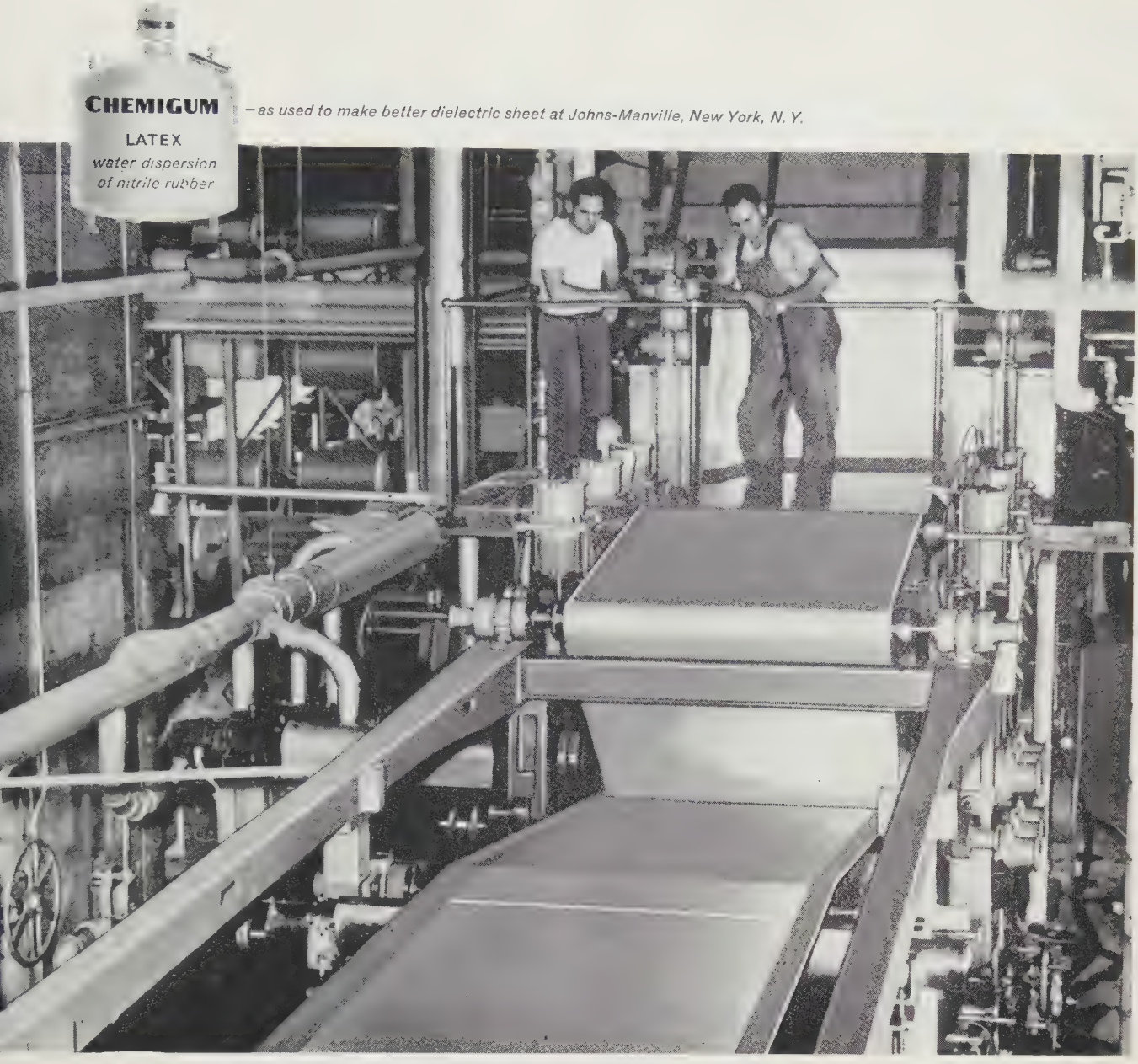


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# Vocational Training of Young Papermakers in Western Europe, Eastern Europe, and North America*

In order to give a survey on the different types of vocational training in the paper industries of Western Europe, Eastern Europe, and North America, the "Schulverein der Papier- und Zelluloseindustrie Österreichs" carried out an investigation, in the course of which competent authorities in the producer countries were approached for information.

It can be stated with great satisfaction that the approached central organizations readily complied with the request of the "Schulverein" and made available, in many cases, extensive information on their vocational training systems. The statements given below are based on information received from the respective countries themselves.

In order to debar all misconceptions it should be noted that in the following only papermaker apprentices are under discussion and by no means those so-called trade apprentices who go in for the career of an artisan such as locksmith, carpenter, electrician, etc.

## WESTERN EUROPE

### *Austria*

The central organization in charge of all problems of vocational training within the Austrian pulp and paper industry is called the "Schulverein der Papier- und Zelluloseindustrie Österreichs," which is located in Vienna VI., Gumpendorferstrasse 6.

The Austrian pulp and paper industry, with its papermaker school in Steyrermühl, Upper Austria, owns a central training institution, in which papermaker apprentices are trained according to uniform guiding principles. Vocational training is based on a collective agreement between the Fachverband der Papier-, Zellulose-, Holzstoff-, und Pappen-industrie Österriches and the Trade Union of Workers of the Chemical Industry, concluded in August, 1953. Theoretical instruction is given on the premises of the Paper-Maker School—attached to the Papierfabriks- und Verlags A.G. Steyrermühl—which is run as branch of the vocational trade school in Gmunden, Upper Austria, while practical training is given in the training workshop of the paper mill Steyrermühl respectively throughout the plant itself. A home, constructed to most up-to-date lines, which has only been opened in September, 1959, and in which most of the apprentices live, is located in the immediate proximity of the Steyrermühl mill.

Apprenticeship regulations are based on a three years' identure between the parent firm and the apprentice or his legal representative. The hiring of apprentices is exclusively done by the individual pulp and paper mills themselves. Candidates for the papermaker school must have completed their 14th year, anticipating, as a preliminary condition eight years of previous school training.

Training is done according to an accurately laid-down schedule and lasts for three years. The school year invariably starts on September 1 and lasts until August 31 of the following year including a four weeks' holiday. The first two years of his training the apprentice spends in the papermaker school in Steyrermühl. At the beginning of the third training year he returns to his parent firm and, at the end of this year, he is to come back to Steyrermühl again, in order to attend a seven weeks' preparatory course for the final examination.

In the first year, training starts with twenty week basic course for metal working in the training workshop. After that the apprentice works for five weeks in an electro workshop, eight weeks in a repair shop, further nine weeks in the locksmith shop, tinsmith shop, in the carpentry and saddlery and, at last, gets instruction, for six weeks, in laboratory works. Simultaneously with this practical tuition courses are given on various subjects such as commercial arithmetic, technical knowledge, drawing, factory organization, raw materials, and correspondence. At the end of the first training year the apprentice should have already some perception of all spheres of plant operation, and to be able to handle the machines properly and make simple repairs by himself.

In the second training year the apprentice works already in two-shift operation where he is made familiar with works on the woodyard, in the groundwood mill and in the pulp mill, in the laboratory, in the boiler house, with the beater and with the paper machine. Through theoretical tuition he will obtain further knowledge in commercial arithmetic, expert drawing, plant organization, raw materials, correspondence, technology, citizenship, electrotechnical engineering, and trade-economic arithmetic.

In the third year of training the apprentice will return to his parent firm where he will work, according to age group, in two-shift or three-shift operation, being trained in conformity with the requirements of the plant. Before graduating he is called back once more to Steyrermühl where he will get final theoretical instruction in a seven weeks' course.

Following the seven weeks' tuition in the third year of training there will be a final examination in Steyrermühl, comprising written, verbal, and practical examinations. The Examining Committee is composed of first-rate experts of the paper industry and a representative of the Apprentice Department at the Chamber of Industrial Economy Upper Austria.

To this date 280 apprentices have attended the papermaker school of the Austrian pulp and paper industry, or are still being trained there. One hundred and eighty apprentices have finished their studies successfully. Thirteen per cent of the trained young paper

* Report prepared by Schulverein der Papier- und Zelluloseindustrie Österreichs, Wien VI, Gumpendorferstrasse 6.

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makers have either started work with another paper mill or went abroad, or else changed over to a different profession, or have been given notice; 87% of the trained papermaker apprentices remained in their original parent firm.

***Federal Republic of Germany***

The central organization competent for questions of vocational training in the German pulp and paper industry is the "Vereinigung der Arbeitgeberverbände der deutschen Papierindustrie e.V." with its seat in Wiesbaden, Schöne Aussicht 57.

In Germany, papermaker training is accomplished by indenture. The papermaker, board maker, and pulp maker are training vocations recognised by the state on the basis of officially approved training programs.

In Germany, a youth to be trained as papermaker is called an "Anlernling" which term means that the apprentice does not get final training and, by vocational training alone does not achieve the ultimate training goal.

The indenture runs from one and a half to two years. Training may start at an age of 15 at the earliest. Recruiting of the apprentices (Anlernlinge) is done by the mills themselves.

Training is divided into a practical and into a theoretical part. Practical training is given exclusively in that plant that had taken on the apprentice. There do not exist any central guiding principles for practical training.

Theoretical training normally takes place in vocational training schools for which three years' attendance are legally provided. Those apprentices, in whose vocational training school there does not exist a papermaker class, because within the area covered by that vocational training school there are not enough paper mills, have an opportunity to obtain proper vocational training in the papermaker school in Gernsbach, Baden. In the papermaker school Gernsbach—which also comprises an apprentice home—the number of legally provided school hours (an average of 450 hours) are absolved in two school years of 10 weeks each. Apprentices subject to vocational training, attending the Gernsbach school are, of course, exempted from attendance at their respective vocational training schools at home.

Upon completion of practical and theoretical training the apprentice is supposed to pass a final examination before a board of examinators of the pertinent Chamber of Industry and Trade and, when passed successfully, he will obtain a certificate of apprenticeship qualifying him as a young papermaker.

So much for the German method of the training of qualified skilled workers. As regards education possibilities for higher qualified professions within the paper economy there is, besides the well-known college in Darmstadt, another education opportunity destined for the training of paper engineers at the Oscar von Miller Polytechnicum in Munich, Bavaria. This is the only engineering school of no college level standard in the Federal Republic of Germany where engineers and technicians are being trained for pulp and papermaking. At the same time, it represents the only Academy in Europe where engineers and technicians are being trained for paper and paperboard processing. The acceptance of applicants at this school does not depend on a certificate of maturity of one of the first-grade secondary schools. Only pupils with a minimum age of 17 are accepted. Training of a paper engineer lasts for six half-year terms, that of a paper technician for three half-year terms. More than 700 paper engineers and technicians have passed the paper-technological department at the Oscar von Miller Polytechnicum since it came into existence, ten years ago.

***Netherlands***

While there is vocational training in the Netherlands it is, however, not centralized and not uniform in its instruction programs. Widely known is the papermaker school in Velsen. There is, moreover, a vocational training school on the Veluwe that was founded by some paper mills. Finally, there is a vocational school for the training of apprentices in the paper industry in the province of Limburg where a legally approved training system is being used.

Before going into the details of the various training schools it seems necessary to point to a particular fact that has essentially influenced the development of vocational training in Holland.

In the Netherlands, all pupils get six years of elementary school training. Following this, pupils, who are then about 12 years old, are supposed to chose a definite training type, i.e., secondary school, higher school, or a vocational or continuation school. Attendance of vocational schools lasts from two to three years. After having received eight years of school training compulsion to attend school ends for every pupil in the Netherlands. Then the pupil is 14 or 15 years old.

The problem of vocational training in the Dutch paper industry was that there was no possibility to take on pupils for training because, in the Netherlands, all mill work is strictly forbidden for juveniles under 14 years of age. Only when a pupil has reached his 14th year, training in industry may start. Normally, however, the future profession is chosen already at a time when the pupil, at the age of 12 leaves elementary school. The paper industry, on the other hand, was unable to accept any of these juveniles because apprenticeship would have been regarded as mill work. The consequence of this was that influx of trainees into the Dutch paper industry was but scarce.

So, in 1951, it was decided to erect a papermaker school in Velsen. This was similar to general vocational training schools in Holland and it was given permission by the state to accept pupils coming directly from elementary school.

The papermaker school in Velsen was developed from apprentice training in the paper mill Van Gelder Zonen. Training time is three years, whereby theoretical tuition is given during all three years in the paper mill Van Gelder Zonen, while practical instruction is given only in the second and third years. Total training program was adapted to fit the mental development standard of pupils of 12 and 13 years of age; apprentices are not called in for mill work. Aim of the training scheme is the training of capable workers by suitable general and technical education of apprentices. Number of

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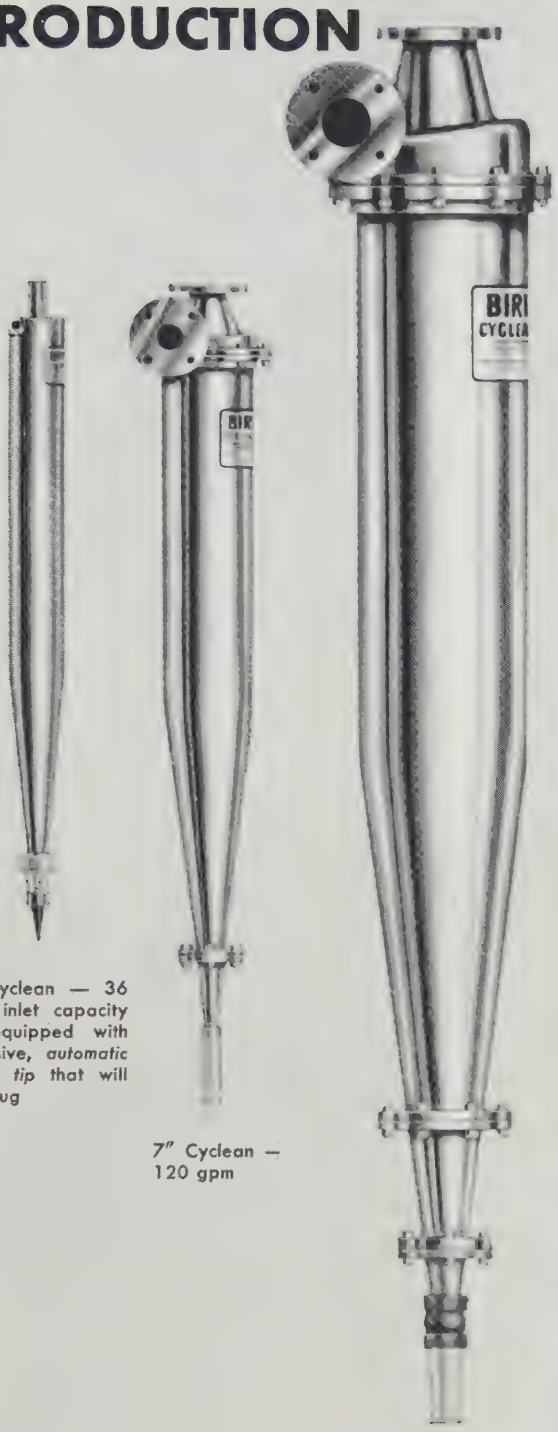

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pupils, in 1958, in this papermaker school amounted to approximately 63.

In 1958, some Dutch paper mills founded another papermaker school on the Veluwe, in the form of an endowment. Also there length of training is three years. Object of training is the same. By the end of last year 25 apprentices were in the process of being trained at that school.

Finally, there is yet another papermaker school in the province of Limburg, the instruction system of which is, however, different to the previously mentioned schools. There, school curriculum provides, among others, instruction in the following subjects: Transport of raw materials and finished products, handling and maintenance of auxiliary means used at transport, the packing of finished products, operation and maintenance of paper machines, beaters, equipment machines, quality judgment as well as knowledge of same, purpose and use of usual security regulations. Training time at this school has also been fixed at three years.

***Sweden***

The "Sveriges Pappersbruksförbund" is the authority in charge of the questions of vocational training in the Swedish pulp and paper industry. It is located in Stockholm, Södra Blasieholmshamnen 4 A.

Training of skilled workers in Sweden is, at the present time, still decentralized. A typical example for this represents training at the firm Stora Kopparbergs Berglags A.B. in Borlänge. The training plan worked out by this mill provides four years of training of 40 weeks each for paper mill workers. Training starts with basic training in the workshop and, in the course of the second year, leads to step-by-step training at the various production and auxiliary machines. The third year is devoted to training in those production departments and on those machines for which the apprentice has shown particular skill or special interest. The fourth training year is devoted to perfection in all pertinent works. Vocational school training runs parallel to practical training and is given particular attention during the first two years, while during the third and the fourth year only a few hours per week are devoted to theoretical training.

The construction of a central papermaker school for the whole Swedish pulp and paper industry, with its seat in Markaryd, Smaland, about 150 kilometers east of Göteborg, has already started. The layout of the school is planned to be in conformity with most up-to-date experiences and will lodge 100 apprentices. Estimate of construction costs of this school, which will run also an apprentice home, is 20 million Schillings, which will be raised exclusively by the members of the Paper Mill Association. Detailed training plans have not been worked out yet; however, in certain ways they will be similar to the training scheme practised in the Austrian papermaker school. Length of training will be two years. The object is not only the education of qualified trainees but also to provide a basis for advanced training in master courses. The Swedish paper industry has the possibility to avail itself already now of the central master school in Markaryd for this purpose.

The new papermaker school will permit training of 50 apprentices per year. Since the Swedish paper industry, at present, employs approximately 50,000 employees, comprising workers and office personnel, the annual training capacity will amount to about 1% of the total employed.

The above-mentioned Master School in Markaryd is a centralized training institution for the member firms of the Swedish Paper Mills' Association destined for their future masters (in Sweden called work leaders). It is characteristic for the Swedish industry that masters, while usually coming from the workers level, can obtain their position only after having been thoroughly trained, it may have been on the spot in the own plant or else in the central master school. The Master School of the Swedish paper industry originally was a pure, so-called "People's College," a continuation school of voluntary basis, without ties to any business lines, which received municipal or state-side grants-in-aid; students had to pay moderate contribution fees which, in many cases were borne by their employers. This People's College still exists today, but probably because of its central location in the South of Sweden and, moreover, because of the close proximity to a paper mill, a master school for the Swedish paper industry was linked up with it, whereby the latter is sponsored by the Paper Mill Association and subsidized by its members. The Master School arranges courses that last for three weeks. Participants are exclusively employees, who already work in the capacity of a master in their firms and who have already received basic training in their mill for this profession. Expansion of study programs and extension of courses are planned.

***Finland***

There is no centralized training scheme for young workers in the Finnish pulp and paper industry. Mills recruit the young people they require to replenish their staff from general vocational training schools. These vocational training schools do not run special classes for pulp and paper technology so that apprentices coming from these schools are dependent on practical experience to be gathered in their employing firm.

Five Finnish mills have set up ordinary training workshops where their apprentices are trained in methods practised by the pulp and paper industry. Length of training is three years. In those five training workshops approximately 75 young papermakers are being trained per year, which corresponds to more than 2% of a total of 37,000 employees.

***Switzerland***

There are no centralized training facilities for papermakers in Switzerland. Although the plan to create a training profession "Papermaker" has been repeatedly discussed, it had not been able to carry this scheme into effect.

However, the paper mill Biberist has set up an excellent school already many years ago, where young workers of this mill as well as also employees of three other enterprises (i.e., the paper mills Utzenstorf and Balsthal and the pulp mill Attisholz) are being trained.

In most cantons of Switzerland two to three years attendance of a vocational or continuation school is obligatory for juveniles having passed ordinary schools. The paper mill Biberist succeeded in pressing home its

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point with school authorities that this obligatory vocational training was conferred on their school.

In respect of training at Biberist the following points seem worth mentioning:

1. The paper mill Biberist and the three other firms mentioned above have made it a point that, on principle, all newly put on workers pass that school, even those that are to remain unskilled workers.

2. Training program is comprehensive and surpasses deliberately power of conception of a part of the pupils. This is put up with in the interest of the more gifted pupils on the one hand, while on the other hand, it is a well-known fact that mentally some youngsters develop comparatively late, and later gladly resort to the notes they took down when in school.

3. Training of apprentices usually lasts for one year. In 1958, a second training year was introduced for the first time, for the purpose of training higher qualified trainees. During this second training year, on the one hand, the best pupils from the first year continue their studies, while also younger workers who have been already working in the plant for several years and who seem to be suited for advanced training attend this second year training course. To a certain extent, this second training year also provides the opportunity for apprentices to gather experience in other paper mills also.

4. Since 1943, the school compiles comprehensive school statistics. In the course of this 16-year period, 290 pupils attended the school, of which 92% completed their studies successfully. Of the fully trained young men 71% remained with their parent firms, 29% switched over to other firms or into other lines of business, or else were given notice by their mills.

***Great Britain***

There is no centralized vocational training in Great Britain. The objection to this by the English paper industry is accounted for by the fact that conditions vary so widely in respect to mills, as well as with regard to goods produced, that a uniform training scheme does not seem to fit the purpose. For this reason, training of skilled workers is carried out individually by the mills themselves.

In 1946, the National Union, the Employers' Federation of Papermakers and Boardmakers and the Trade Union of the English paper and board industry published jointly drafted guiding principles and recommendations for the recruitment and training of juveniles for the papermaking and boardmaking industry.

***France***

The French paper industry likewise does not dispose over a school for the training of skilled workers, however, according to information received, the establishment of schools for apprentices is contemplated. For the time being, skilled paper mill workers are trained in the mills.

The existence of the French papermaker college in Grenoble must be mentioned. This school is the only university in France where special studies to become a paper engineer are rendered possible. Schedule of studies provides three years. Approximately 15 students annually are being trained as paper engineers. The college was founded in 1907 by the Association of French Paper Manufacturers. Today it has the legal form of a joint stock company. It is accommodated in the Polytechnical Institute of Grenoble.

***Italy***

Italy has neither a papermaker school nor a centrally controlled training system. Some paper mills provided facilities for workshop schools but these serve exclusively for the training of their own personnel.

In Fabriano there exists a technical-industrial States Institute, that is a type of secondary school with a paper technical department.

Moreover, there is a training institution in Milan, designed for the technical personnel of the Italian paper industry, in which speed courses of about two months duration are being held on paper technology and paper chemistry. These courses may be attended also by technical apprentices provided they can prove to have had two years practice in a paper mill.

***Belgium***

In Belgium there does not exist either an official or a private institution for vocational training or workers of the paper industry. Training of young people is generally done by the mills themselves.

***Denmark***

Also in Denmark no centrally controlled training system is practised. Skilled workers are obtained via the career of unskilled worker by training in the paper mills.

***Norway***

It is interesting to note that Norway also has no centralized training scheme for the pulp and paper industry. All types of skilled workers' training are left to the initiative of the individual mills.

## EASTERN EUROPE

To begin with it must be stated with regard to the question of industrial training that, in Russia and in all other Eastern bloc countries, there are, at present, revolutionary reformatory efforts in progress with respect of all training systems. Within the frame of these reformatory endeavours the technical vocational training school system will be reorganized in a uniform manner.

Demand for skilled workers is met either by taking on adequately pretrained juveniles, or by the training of artisans, who are specially trained for a particular line of business. Education of juveniles is exclusively state controlled. According to requirements trainees are allotted to the various lines of business and expert training is constantly adapted to fetch-up demand and technical progress. In the course of the training process particular stress is laid on close connection with practical work. This is achieved mostly in a way that an industrial plant (basis plant) accepts sponshorship for a vocational training school belonging to the same line of business. Specially trained teachers are used for giving instruction in vocational training schools as well as for training in the basis plants. In every case the aim is to place trainees as productively as possible and a good part of the training time—usually 40 to 70%—is devoted to training in training workshops or in the basis plants.

Here, Yugoslavia and Poland are quoted as examples for the manner in which training of Juveniles in the paper industries of Eastern Europe is carried out systematically and according to meticulously laid down principles.

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*Yugoslavia*

In Yugoslavia there exist, at present, two schools for the paper industry:

1. The papermaker school in Laibach-Vevče where young men are trained to qualified workers. Annexed to this school is a home in which, with few exceptions, all pupils live.
2. The technical secondary school in Laibach with a department devoted to paper, which exclusively trains technicians for the paper industry.

Training in the first-mentioned papermaker school in Laibach-Vevče lasts for a total of three years. Apprentices are taken on by the paper mills, which also bear total training costs. Pupils receive an apprentice compensation and social insurance.

The training schedule is arranged in such a manner that apprentices are trained for a period of six semesters. Theoretical tuition is given during five semesters, four days a week. Practical training is divided into three parts: coordination practice, vacation practice, and semester practice. Coordination practice is taught during the first five semesters on two days per week in the paper mills located in the proximity of the papermaker school. The length of vacation practice is five weeks and has to be performed by the apprentice following the first school year, during his vacation time, in his parent plant. Semester practice is carried out during the sixth semester in the best organized paper mills of the country without being followed by more theoretical instruction during this last semester.

The whole instruction plan is wound up according to a meticulously planned program. Specially picked expert teachers conduct not only theoretical but also practical training. Three years' training ends with an examination whereupon the young papermakers return to their parent firm.

In the papermaker school in Laibach-Vevče there exists a department which provides the opportunity for workers coming from other lines of business to be retrained to learn the paper trade. For these workers re-schooling lasts for two years and those having passed successfully get the same qualification as the pupils proper of the papermaker school.

*Poland*

The Polish pulp and paper industry also seriously endeavours to create a skilled workers' elite by adequate vocational training in training schools particularly equipped for this line of business.

One of these schools is the papermaker school in Jezionie near Warsaw. There juveniles as well as workers are trained in pulp and papermaking. Moreover, the same school trains juveniles for the profession of trade specialists.

Training time is five years for papermaker apprentices and three years for special trade apprentices (artisans). Pupils receive general and expert training in respect of pulp and paper technology as well as of metal working. An important part of the training plan consists in general education. Practical instruction is given in the training workshops or in various departments of the local pulp and paper mills and in mill laboratories. In addition to this, apprentices are obliged to work twice, for one month each time, in a paper mill during his training period.

It is noteworthy that Polish pulp and paper mills make known their annual need for young papermakers and tradesmen and, it is the general practice to cover their requirements for trainees with these schools.

## NORTH AMERICA

*U. S. A.*

In the pulp and paper industry of the United States there exists neither a centralized training system nor is training of skilled workers effected according to uniform rules. Training of skilled workers in American paper mills is, in general, based on the principle of "training of workers during the working process itself." For this reason, in most cases, there does not exist a definite training program. If there are any training plans at all they vary so widely from firm to firm that it would be quite impossible to define a general line. The same applies to the field of trainees' education where firms do not know of any cooperation.

In this connection, however, it is probably worth mentioning that in the United States, in general, more efforts are made than in Europe to obtain suitable trainees. This aim is, in many cases, arrived at by giving the pupils of the local schools an opportunity to inspect the mills. In addition to plant visits, representatives of firms often hold lectures in the schools, or else pupils and students are given the chance to work as temporary trainees during their summer vacation.

*Canada*

In 1957, the Canadian Pulp and Paper Association asked its member firms how they obtained their regular staff. Fifty-one firms participated in this all-round enquiry. The result was as follows:

20% of skilled workers had come from other plants.
46% had been trained from originally unskilled workers.
10% had undergone proper apprentice training.
24% had had other training possibilities, mostly as for specialists.

As can be seen from these figures, apprentice training does not play by far the important role in Canada as it does in Europe. This accounts for the fact that there is no centralized apprentice training system practised in the Canadian pulp and paper industry. The firms usually train their skilled workers according to their own methods which, in many cases, are based on the various training regulations in force in the different Canadian provinces as well as on the standards set by local vocational and continuation schools.

Up to now, the Canadian paper industry objected to a centralized skilled workers training scheme because it is of the opinion, similar to the English industry, that conditions vary so much from plant to plant that each firm must develop its own training program, which is individually suited to the plant's requirements.

Nevertheless, the Apprentice Committee of the Canadian Pulp and Paper Association took up the problem of vocational training and only recently issued recommendations and guiding rules for the introduction of an apprentice and workers' training scheme referring to legal regulations in the various province states, to its member firms.

In respect of the training of skilled workers in the Canadian pulp and paper industry it is worth mentioning that continuation courses for workers play an al-

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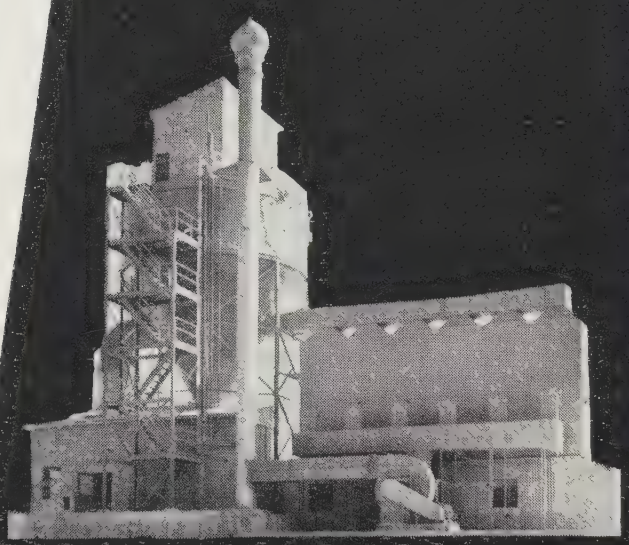

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most greater part than apprentice training, wherby attendance of those courses is, in most cases, financially supported by the firms.

## SUMMARY

In summing up the ways and manners of training of young papermakers in the most important producer countries of the world the following facts can be stated once more:

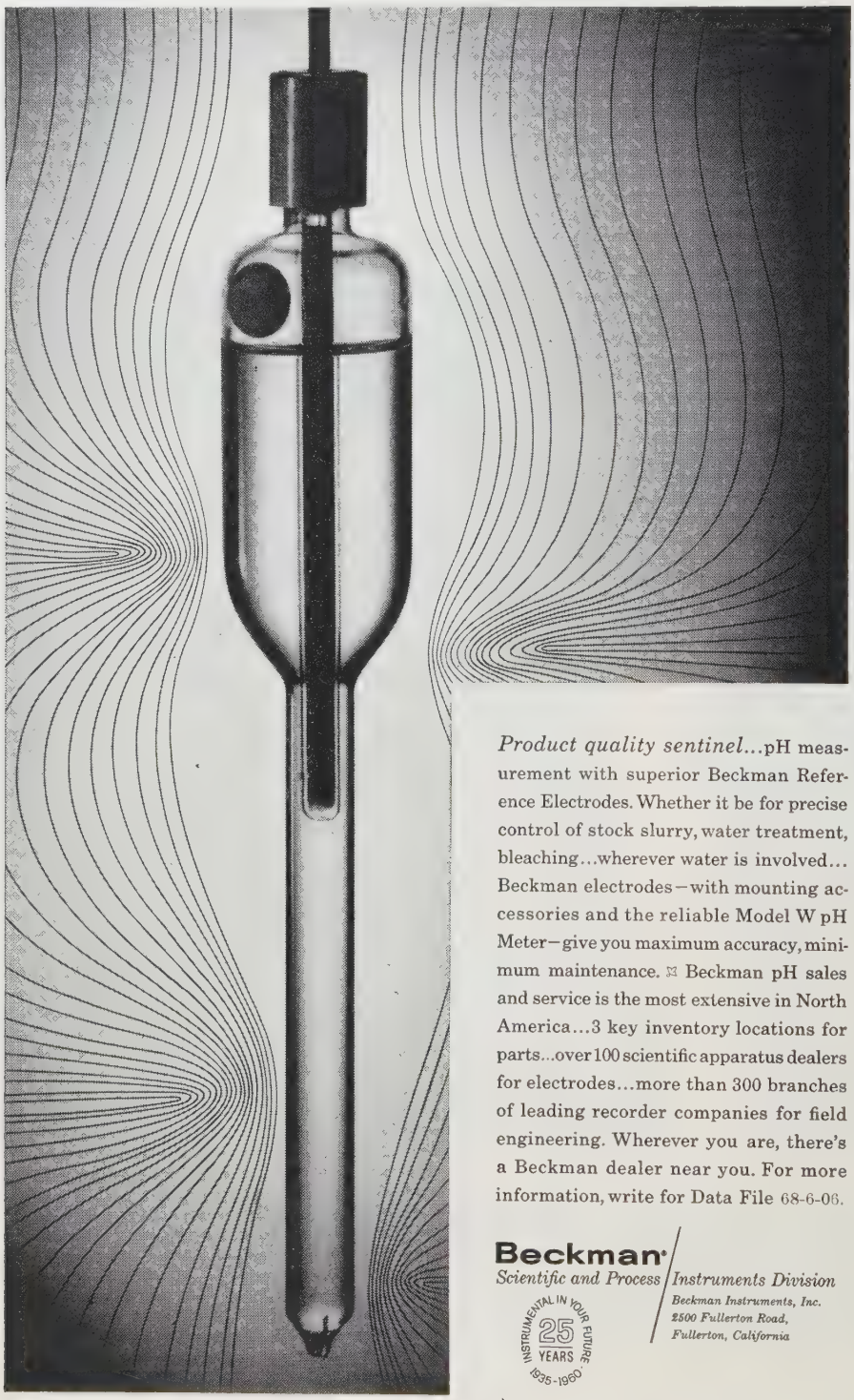
1. Extensively centralized papermaker training exists, in Western Europe, besides Austria, only in Germany and in the Netherlands. As early as 1961, however, Sweden will have a papermaker school and practise a centralized training program for young workers.

2. In the rest of Europe there is, for the time being, no training according to uniform rules. In some countries, however, tendencies toward a centralized training scheme could be observed. This is particularly true of Switzerland

3. The North American system of vocational training cannot be compared with the European one. It is worth remarking, however, that especially the Canadian paper industry is intensively occupied with the problem of skilled workers' training and has even issued special guiding rules for a training program.

4. The most intensive training of young paper workers exists in the East European states whose training level is, no doubt, the highest among all investigated countries.

The investigation further revealed that considerably more attention will be devoted to the problem of vocational training by most producer countries in the years to come. The increasing demand for paper in the whole world and the growing mechanization of producer plants forces industry to consider these problems and makes training of suitable workers a vital economic necessity.



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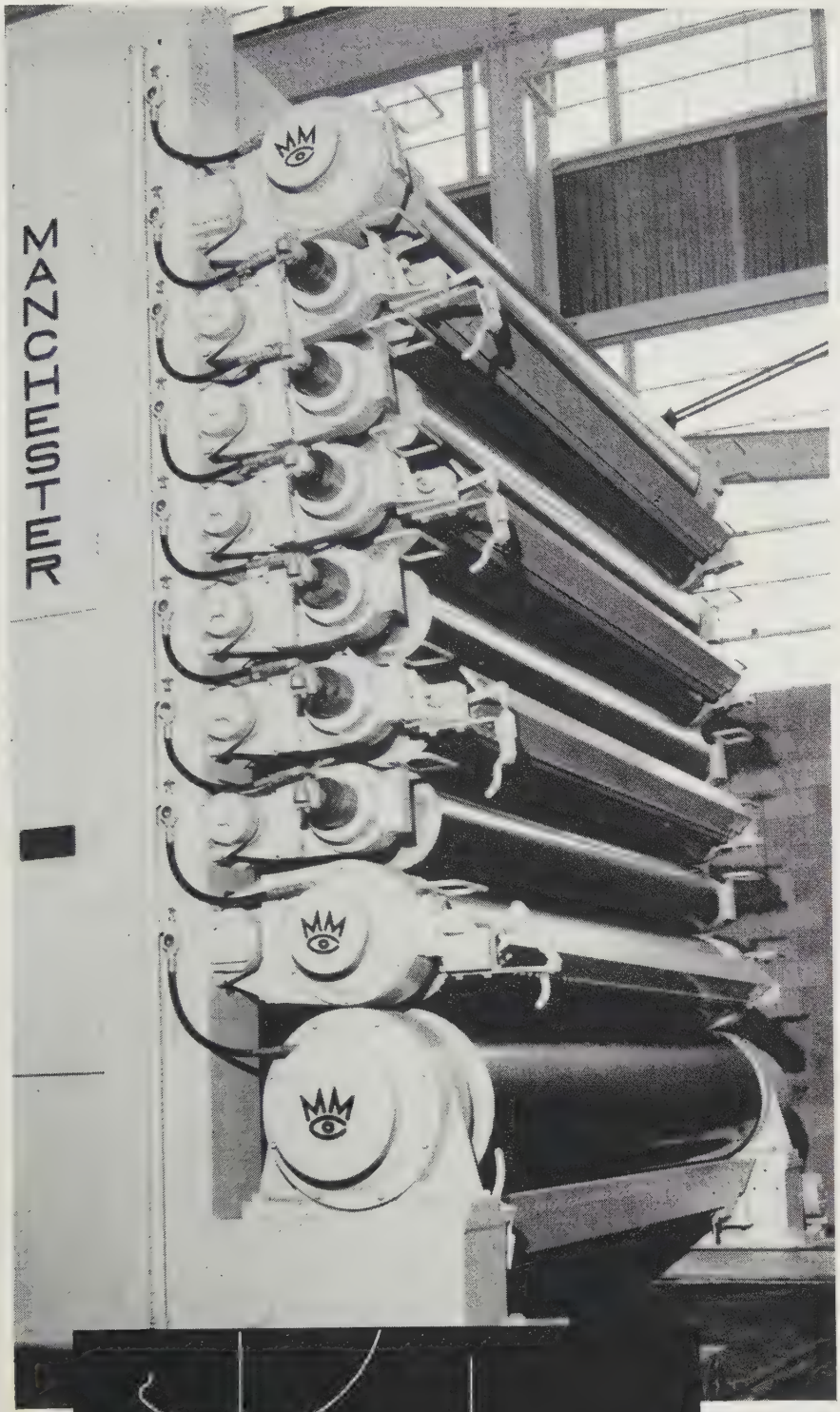


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Many progressive manufacturers of paper mill machinery, like The Manchester Machine Company, rely on Lodding's specialization in doctoring to complement their own manufacturing skills. So, besides serving the mills direct, Lodding acts as sub-contractor to the machine builders.

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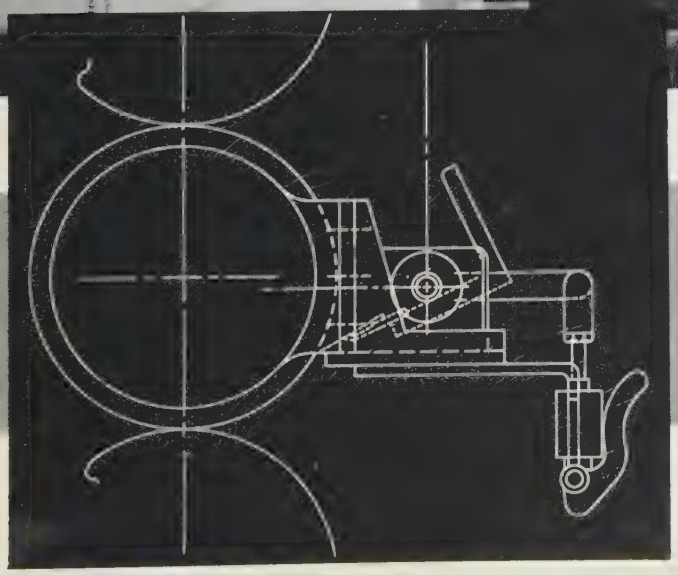

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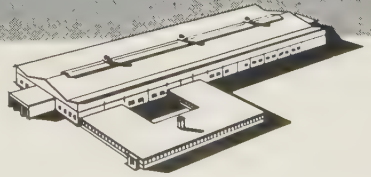

# Petroleum Waxes and the Paper Industry

J. F. BUTTERWORTH

THE paper and petroleum industries in this country each contribute to consumer well being to an extent unmatched elsewhere in the world. Both have enjoyed a healthy, steady growth pattern, and each can regard the other as one of their valuable customers. In reality, the paper industry is our leading sales agent for wax.

Although I do not have reliable statistics on paper industry sales to the petroleum industry, we believe, by projecting our own purchases, the figure to be in excess of 20 million dollars. The paper industry consumes annually, exclusive of fuels and lubricants, over $3^1/_2$ million barrels of petroleum products representing a value of approximately 100 million dollars. Of this amount, over $2^1/_2$ million barrels are petroleum waxes.

I believe you will be interested to know where this wax is used. Our market research and development department has prepared a breakdown that will be of interest because it will indicate, indirectly, the relative size of various paper markets.

According to the U. S. Bureau of Mines, the total U. S. Demand for Petroleum waxes increased by 115% during the 10-year period prior to 1958, or from 561 to 1205 million pounds. This has presented quite a challenge to the Petroleum Industry, and it is no wonder that you have witnessed periods of overproduction and scarcity while the petroleum industry developed new refining techniques and production facilities to meet this growing demand. The paper industry sells, as a part of their finished product, approximately 80% of all waxes produced. So you can see why we regard them as our best sales agent. Approximately 49% of the wax was sold with special food boards, and 22% with waxed paper. The remaining 9% was sold with carbon paper, matches, and miscellaneous paper using wax emulsion sizing.

## MANUFACTURE

To understand the relationship which petroleum waxes have to other petroleum products it is necessary to review the manufacturing process which segregates the hydrocarbons from crude oil into basic groups of products.

The distillation process removes successfully: gas, gasoline, heavy naphtha, kerosine, gas oil, wax distillate, light lube distillate, intermediate lube distillate, and residual lube stock.

This distillation is primarily one of assembling into each group those hydrocarbons falling within more restricted molecular weight limitations. Each group will still contain the basic type of hydrocarbons, i.e., paraffins, olefins, naphthenes, and aromatics present in the crude. Further separation within each group must be done by other methods.

J. F. BUTTERWORTH, Sales Manager, Process Products District, Socony Mobil Oil Co., Inc., Chicago, Ill.

### *Paraffin Waxes*

Paraffin waxes are obtained by further processing wax and lube distillates. The process involves dewaxing and de-oiling by various "sweating," solvent refining, and acid treating processes. The degree of refining will determine the grade, i.e., slack wax, scale wax, semirefined, or fully refined wax. Of more recent development is the production of intermediate waxes from intermediate lube distillate, to segregate waxes that have characteristics which resemble both microcrystalline and fully refined waxes.

The paraffin waxes are mixtures of straight chain, or normal hydrocarbons ranging from approximately $C_{20}$ to $C_{30}$. The complexity of their structure can be appreciated better when you consider that over 4 million structural isomers are possible. It is important to remember that they differ from the oils from which they are derived only in relative paraffinicity, which slight chemical difference is responsible for their higher melting point.

### *Microcrystalline Waxes*

The residuum is the source of microcrystalline waxes.

**Estimate of 1958 U. S. Wax Consumption by End-Use**

| | | *Total U. S. wax consumption, million lb.* |
|---|---|---|
| I. | Packaging uses | |
| | A. Special food board (593,000,000 lb.) | |
| | 1. Milk and juice cartons | 400 |
| | 2. Milk bottle caps and closures | 11 |
| | 3. Cups and round nested containers | 125 |
| | 4. Frozen food cartons | 20 |
| | 5. Butter, oleo, shortening, and ice cream cartons | 20 |
| | 6. Paper cans[a] | 2 |
| | 7. Miscellaneous food board[b] | 15 |
| | B. Waxed paper (275,000,000 lb.) | |
| | 1. Bread baking industry[c] | 71 |
| | 2. Resale consumer products[d] | 65 |
| | 3. Specialty papers | |
| | a. Food | 66 |
| | b. Nonfood | 9 |
| | 4. Glassine and greaseproof | 40 |
| | 5. Tissue stock (under 15 lb.) | 6 |
| | C. Laminations of paper to foil and board | 15 |
| | D. Fiber cans and drums | 1 |
| | E. Corrugated containers | 2 |
| | Total for packaging use | 868 |
| II. | Nonpackaging uses[e] | 217 |
| III. | Miscellaneous | |
| | A. Wax emulsions | 45 |
| | B. Other | 75 |
| | Grand Total[f] | 1205 |
| | 1958 Total U. S. Demand[g] | 1205 |

[a] Straight-sided, spiral-wound containers, primarily ice cream containers.
[b] Includes waxed ice cream and food-pail stock.
[c] Wrappers for bread, buns, rolls, etc.
[d] Primarily household waxed paper; includes home freezer wrap
[e] Leather, cosmetics, dental, cheese, pipe wrappings, etc.
[f] Our estimate of total U. S. consumption of all petroleum wax (fully and semirefined paraffins, scale, and micro).
[g] As reported by the U. S. Bureau of Mines in the 1958 Minerals Yearbook.

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These are some of the reasons why most of the nation's leading producers of coated papers and coated boxboards use Calgon. They also call on Calgon's Technical Service for assistance on a wide variety of water problems.

If you have a problem, call on Calgon for assistance. A technical bulletin, "Calgon and Its Applications in the Pulp and Paper Industry" is available on request.

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The process involves dewaxing to obtain dewaxed oil and petrolatum. Further solvent de-oiling of the petrolatum produces microcrystalline waxes. The microcrystalline waxes contain some normal paraffins but consist largely of complicated isoparaffins and ring structures. They range generally from $C_{30}$ to $C_{60}$ and the number of structural isomers possible reaches a fantastic total, in excess of 60 million million.

Because of their great affinity for oil, the processing of microcrystalline waxes is considerably more complicated. A typical solvent de-oiling process is one employing two solvents:

1. Methylethyl ketone, which has *no* solubility for wax.
2. Toluol, which provides solubility for oil at relatively low temperatures used.

Within the limits of the original crude oil, the melting points and hardness of microcrystalline waxes can be controlled by refining techniques involving variations in petrolatum-solvent ratio, temperature controls, etc. The microcrystalline waxes separated are generally dark in color and require further refining by filtration.

It is obvious that microcrystalline waxes are related to paraffin waxes as well as to heavy lubricating stock. The kinship to paraffin waxes is one of similar paraffinic nature, whereas to lubricating oil it is one of comparable boiling range and viscosity. Thus, they are paraffinic waxes but they are appreciably higher boiling (higher molecular weight) than refined paraffin waxes and have a higher viscosity in the molten condition.

## USES

Paraffin waxes, microcrystalline waxes, and blends together with additives are used to produce three important types of paper and board:

*Dry Waxed.* Here there is *no* continuous film of wax on the surface and all wax has penetrated into the space between the paper fibers. The wax coats the fibers and fills the interstices, thereby imparting waterproofness or water repellency. Because of the exposed and connecting links of fibers they still serve as moisture wicks, although to a reduced degree, and entirely moistureproof sheets cannot be produced by dry waxing.

*Wet Waxed.* Here substantially all the wax is deposited as a film on the surface, on either one or both sides. The degree of waterproofness and moisture vapor transmission (MVT) will depend on the uniformity of the continuous film as applied and maintained during service.

*Laminated.* Here two or more sheets of paper or board are bonded with a continuous wax film as the adhesive. The primary purpose of the wax is to provide a moisture vapor barrier. Since paraffin waxes have relatively low bonding strength and are less flexible, microcrystalline waxes are used almost exclusively for laminating. Various additives are used for such specific purposes as (1) special resins—to improve adhesion and low-temperature flexibility, (2) Butyl rubber—to increase viscosity and thereby reduce high temperature delamination, and (3) polymers, such as polyethylenes and polyisobutylene, to impart specific characteristics desired in specialty lamination.

Since most of the waxed paper and board are used in connection with the food industry, recent legislation concerning food adulteration dictates some minor changes in commercial applications. The Food and Drug Administration, charged with enforcing the law have, as of March 17, granted an extension to March 6, 1961, for the use of two types of waxes, pending final approval or modification of specifications.

*Type I Waxes.* Congealing point of 160°F. max. (ASTM D-938); absorptivity at 290 $\mu$ of 0.04 liters per gram centimeter max. (ASTM E-131); oil content of 1.5% max. (ASTM D-721); and color of 20 min. (ASTM D-156).

*Type II Waxes.* Absorptivity at 290 $\mu$ of 1.0 max.; oil content of 5% max.; and color of 3.0 max. (ASTM D-1500).

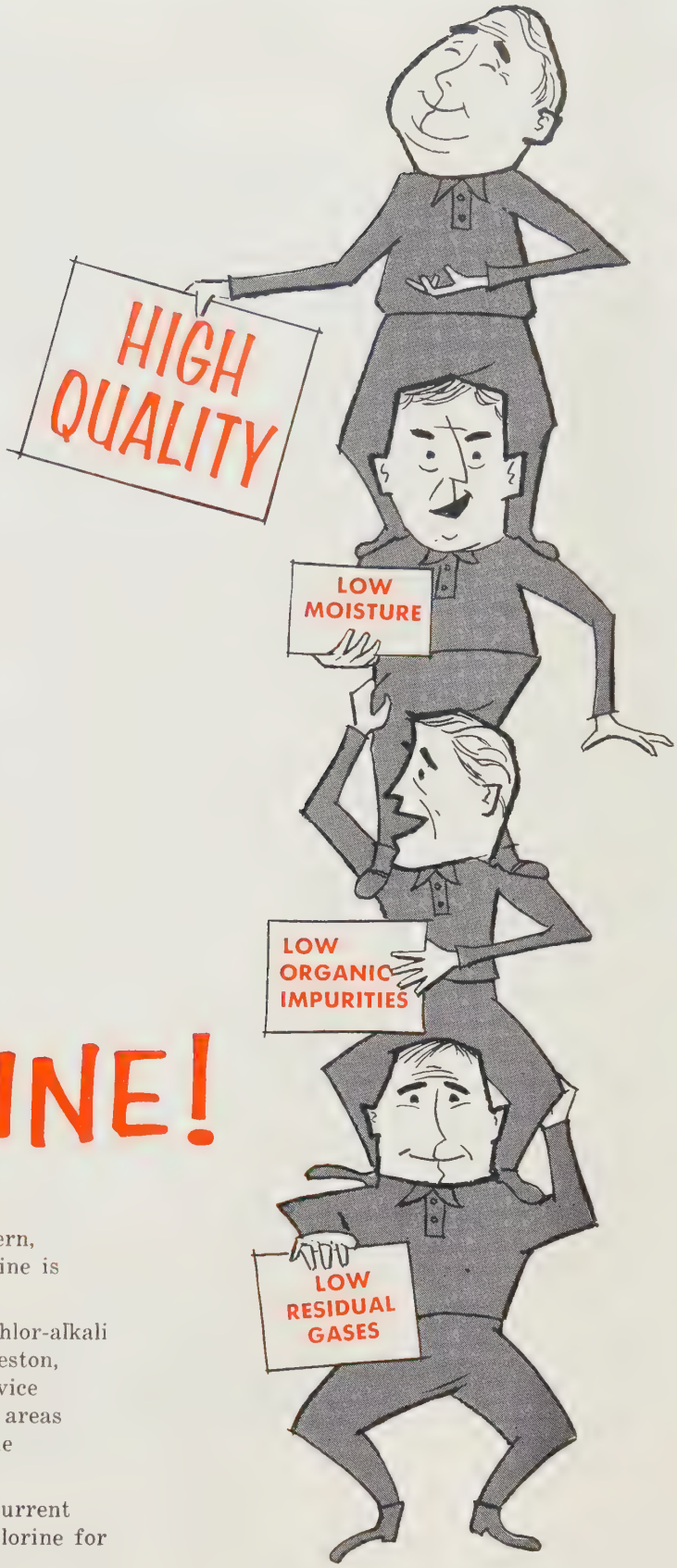
Most fully refined paraffin waxes easily meet requirements of Type I waxes. The ruling eliminates darker microcrystalline waxes from uses in food packaging unless nonmigration can be proved, and this is difficult to do from a practical consideration. For this reason, many asphalt laminated food packages will undoubtedly be discontinued in favor of wax laminated packages.

To properly understand the use of petroleum waxes in paper products, a review of their properties which influenced selection for specific end use is essential.

## PHYSICAL CHARACTERISTICS AND RELATION TO PERFORMANCE

### *Waterproofness*

The basic use for waxes is in conjunction with their resistance to water. For water repellency alone,where MVT is not critical, paraffin waxes are adequate, and

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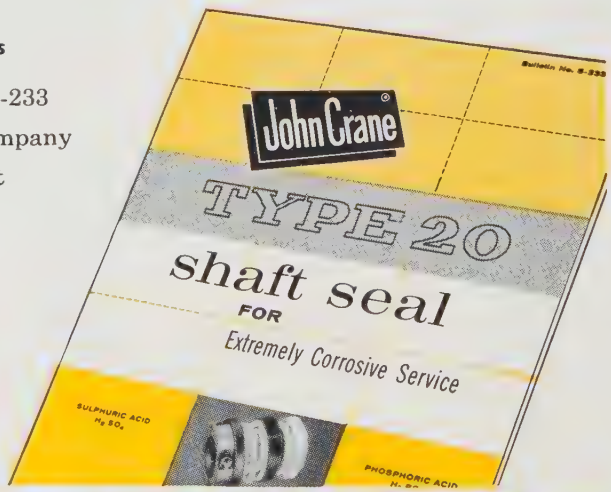

**CRANE PACKING COMPANY**


because of lower cost they are widely used. Here, a dry-waxed sheet will often be adequate unless other packaging requirements such as gloss dictate a wet-waxed sheet. Typical examples are delicatessen papers, drinking cup stock, waterproof paper bags, butcher's wrap, etc.. Production problems are at a minimum since problems of blocking, film flexibility, and gloss are not generally encountered.

When resistance to passage of moisture vapor is important to the finished paper product, it always calls for a wet-waxed or laminated sheet. Here a continuous wax film is essential. Because microcrystalline waxes are more flexible they find wide use either straight or blended with paraffin wax to assure continuity of film during service. Theoretically, a continuous film of any petroleum wax is impermeable to the transmission of either a gas or water vapor. From a practical standpoint, the final MVT rating is influenced by the paper as well as the wax. For example, 4 lb. of wax per ream on glassine (closed sheet) will usually rate better than 13 lb. per ream on same weight sulfite (open sheet).

The important factor is continuity of wax film and the many problems associated with the mechanics and materials of wax application on paper, govern the ability to effect and maintain film continuity. From a physical consideration, paraffin waxes are about equal to microcrystalline waxes as far as MVT is concerned. However, their brittle nature makes it impossible to secure with them a practical, unbroken film that will be effective for most critical applications. Hence, the wide use of microcrystalline wax as a blend with paraffin wax, and as a laminant.

### *Melting Point*

The melting point of paraffin waxes is determined by measuring the heat of fusion which is released when the wax is cooled from a liquid to solid state. (ASTM D-87)—Various grades are available from 125/127 to 150 amp. Amp. designations are 3°F. higher than

. R. CHRISTENSEN

Dryer Section, No. 6 Fine Papers Machine, the Northwest Paper Company, Brainerd, Minnesota

# The Northwest Paper Company

Installation and successful start-up of No. 6 machine completed the current expansion and renovation program at the Northwest Paper Company's Brainerd, Minnesota, mill. This 200″ Beloit Fourdrinier machine has increased daily production of the famous Northwest Pedigreed Papers from 80 to over 200 tons a day. For further details and views, please turn the page.

**details of Northwest's new No. 6 machine at Brainerd, Minnesota** Designed to run in the 2000 fpm range, this 200″ Beloit machine produces Northwest's high-grade writing, printing, and converting papers. Addition of No. 6 machine has tripled production at the Brainerd mill. **(a)** Smoothing press following third suction press; **(b)** straight-through press featuring automatic suction pick-up and sheet-transfer arrangement; **(c)** Beloit pneumatic reel designed to wind 60″ parent rolls; **(d)** motor-operated Beloit streamflow valve; **(e)** Jones-Beloit benchboard controls at press position; **(f)** wet-end Beloit differential-drive units; **(g)** twin open-side Beloit calender stack.

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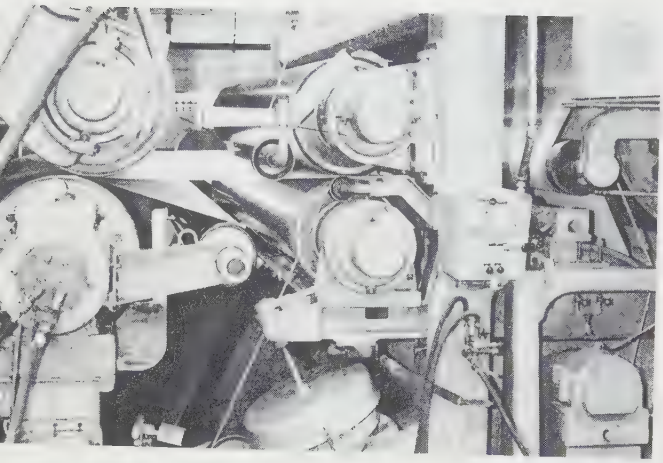

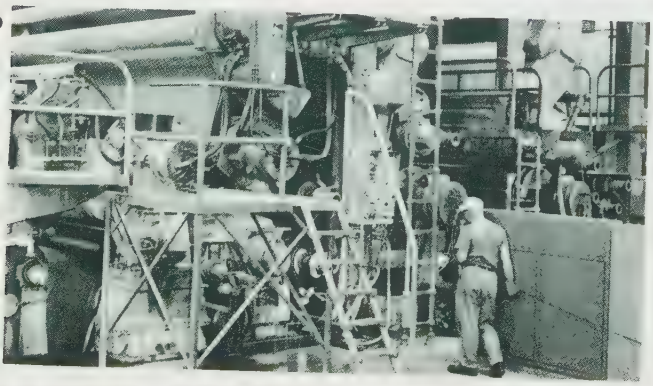

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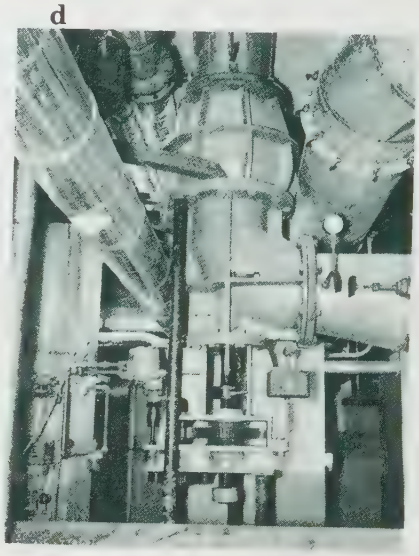

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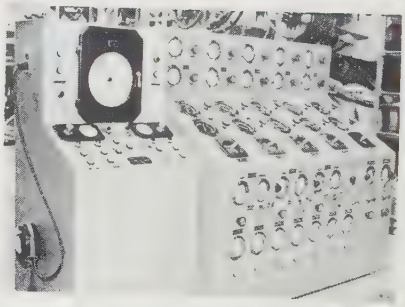

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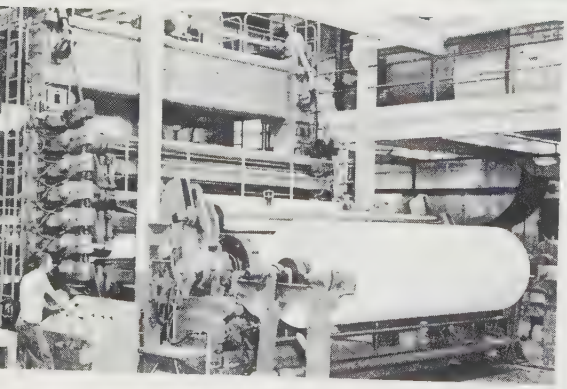

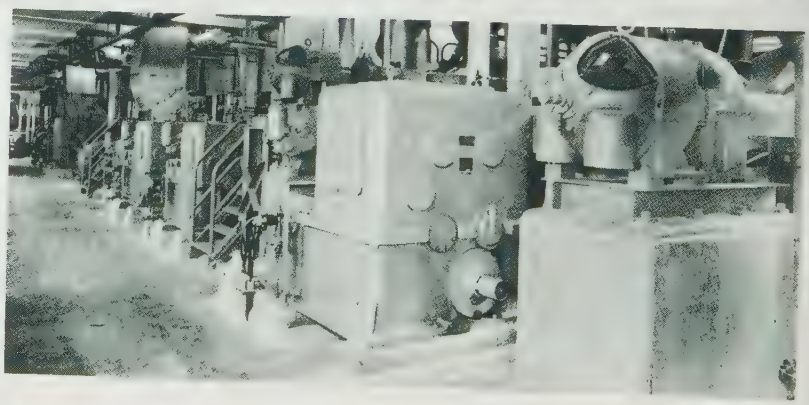

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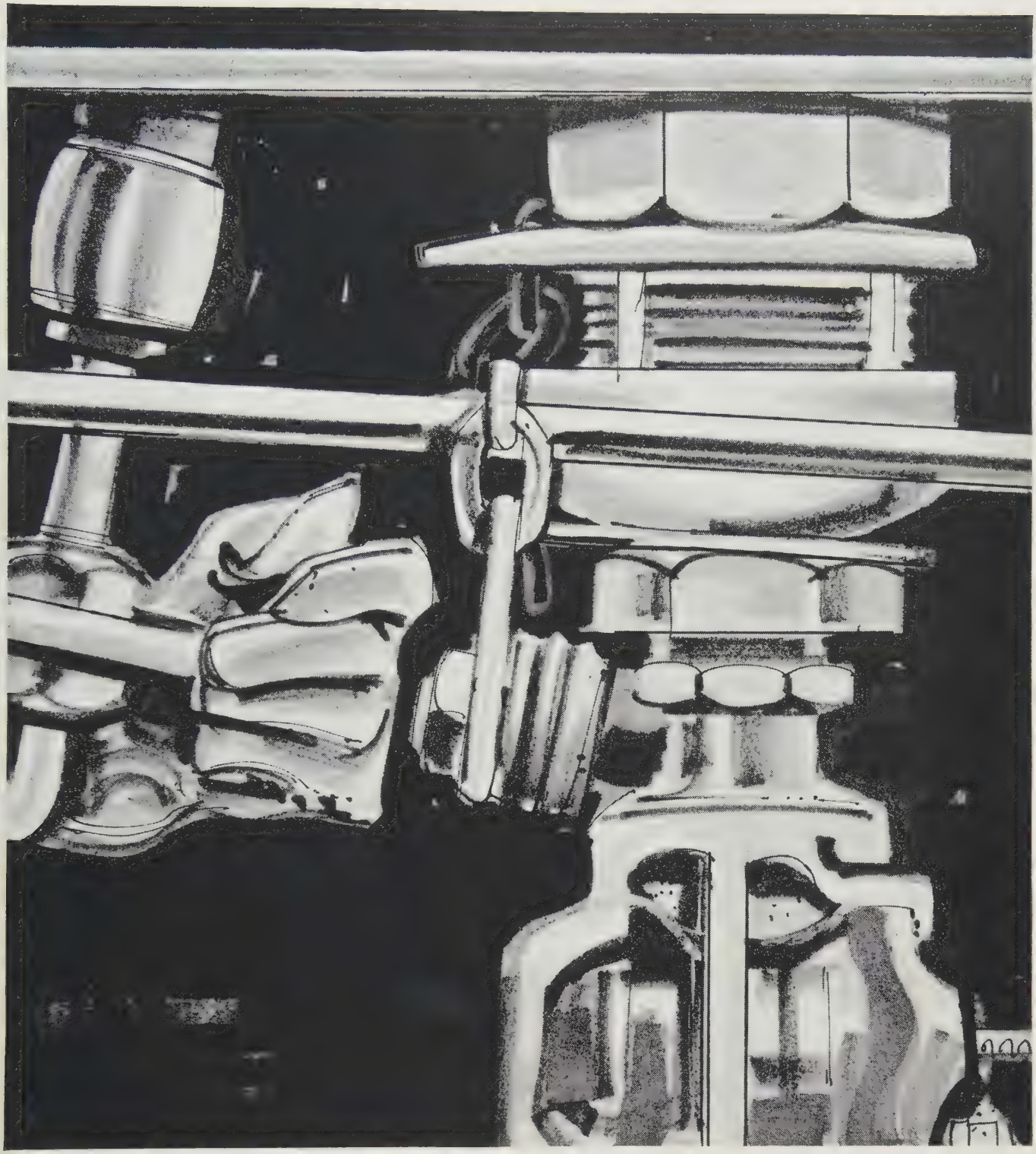

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HOOKER CHEMICALS PLASTICS

ASTM, or Saybolt & EMP. Microcrystalline waxes do not exhibit a clearly defined point from heat of fusion because of the wide range of melting point of the hydrocarbons contained therein. Instead, the ASTM melting point is defined as the temperature when a drop of wax falls from a thermometer bulb (ASTM D-127). Microcrystalline waxes are available with melting points of 140 to 200°F., although most commercial grades are about 170°F.

In considering melting point values for microcrystalline waxes it is necessary to know which method is used. For example, there are other tests: namely, the rotating drop method, and the Department of Agriculture method which give results 2 to 10°F. lower than the ASTM Method. Obviously the service conditions of the package can influence selection of a specific melt point grade.

***Blocking Point***

Blocking points are usually reported as the temperatures at which surface waxed paper will adhere to each other sufficient to effect the wax film. It is a combination of pressure and temperature. To provide relative data, gradient-test bars are used with a standard metal strip to provide pressure. After 7 to 12 hours, the location on the bar of the blocked sheets are related to temperature at that point, and reported as blocking temperature. A 128/130 amp. fully refined wax will usually block at 93 to 96°F. by this test, as compared to 125–130°F. for a 150-amp. grade.

The importance of this characteristic on certain wound waxed stock is apparent.

***Sealing Strength***

In certain applications, such as bread and frozen food wrap, sealing strength is an important requisite. Waxes or blends to be tested are coated on breadwrap stock, as these usually have little or no adhesive strength, and an open sheet is needed to anchor the wax to the sheet. The coated papers are sealed together under heat and pressure, conditioned, and pulled apart by hand. The addition of microcrystalline wax increases sealing strength, and for low temperature applications as much as 75% might be used. Polyethylene is often used to reduce tack. Blending of "three component blends" of this nature requires a thorough knowledge of the characteristics of each component.

***Laminating Strength***

The laminating strength of wax is dependent upon the type of paper or board involved, the adhesive strength of the wax, and the cohesive strength of the wax. For laboratory testing, glassine paper is used. Since little wax impregnation is involved, the results more clearly compare the strength of wax itself.

Our test procedure involves coating one sheet of the glassine with the test wax and then laminating an unwaxed glassine sheet under a given set of conditions. One half-inch strips are then pulled apart at a constant rate of speed. The strength of the bond is measured in grams using a Jolly spring. The test is used only for microcrystalline waxes.

Higher wax loads will improve the laminating strength of the bond. At lower and higher temperatures most waxes lose some of their bonding strength. Hence, the use of resins and butyl rubber for compensating where necessary.

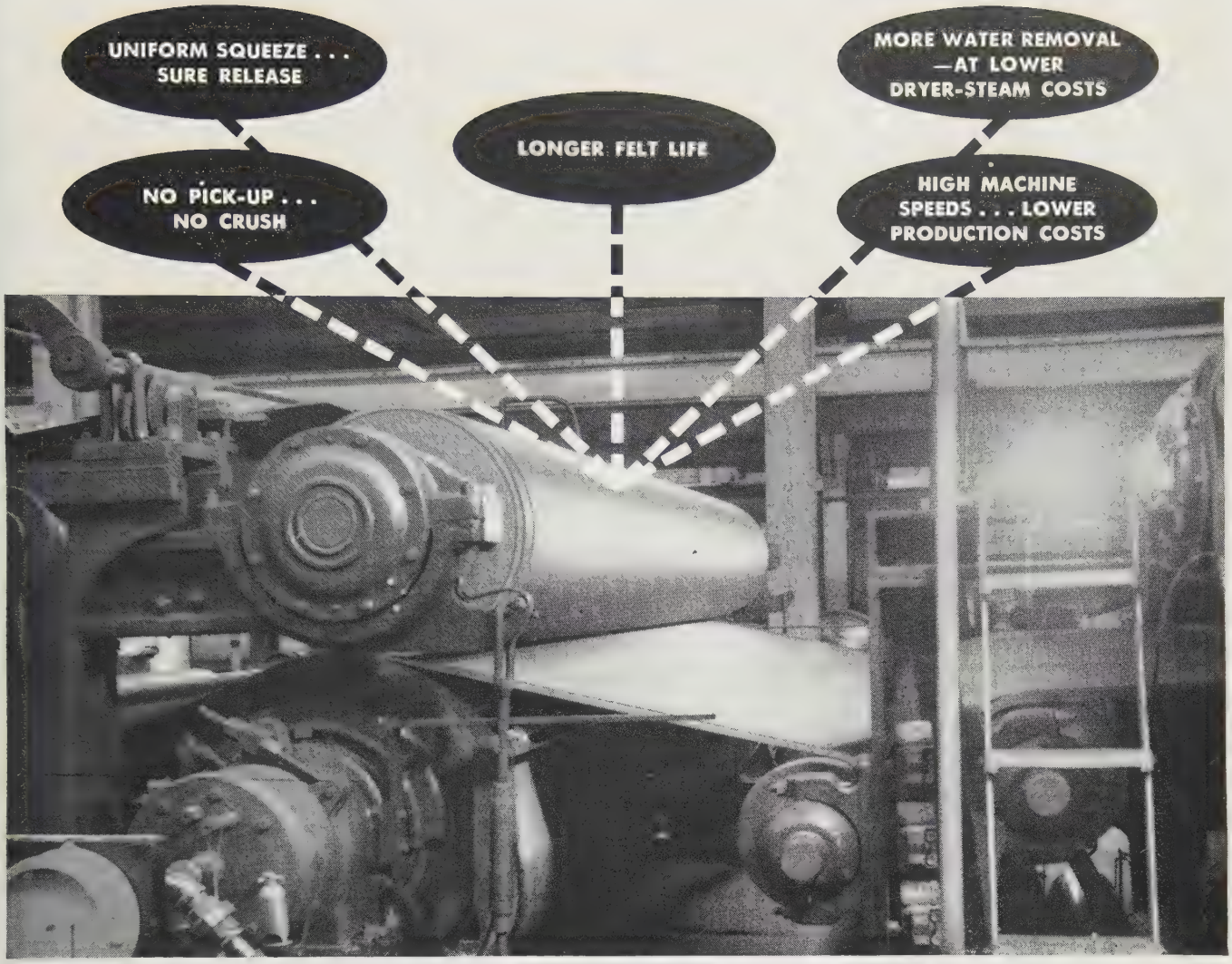
***Straining Tendency***

For those paper where the outer appearance is important, the staining tendency of a wax laminant can be most important. It is closely related to strike through. To test this characteristic, strips of parchment are coated with 40 to 60 lb. wax per ream. A heavy test paper (water leaf type) is placed in contact with the wax film on a gradient bar for seven hours. The test paper (water leaf) is then daubed with water-soluble dye. The stain point is recorded as the temperature of the bar, where the first test sheet shows dye stain. For good laminating grade wax this will be about 123°F. This is not a measure of oil content as might appear at first consideration. Actually, the real cause of stain is the percentage of low melt components. Therefore, the penetration curve becomes a more reliable index of staining characteristics. The curve from 77 to 115°F. is adequate. If the penetration is too soft at 115°F. (above 230) it will undoubtedly be unsatisfactory in critical staining applications.

***Flexibility***

To determine relative flexibility of an unsupported wax film, our laboratories bend under a given set of conditions (load, temperature, etc.) a strip of wax $^1/_{10}$-in. thick and $^1/_2$-in. wide through a 90° angle. Samples are first conditioned for at least two hours. Load is applied steadily by an electric motor.

Microcrystalline waxes are usually tested at 0, 30, and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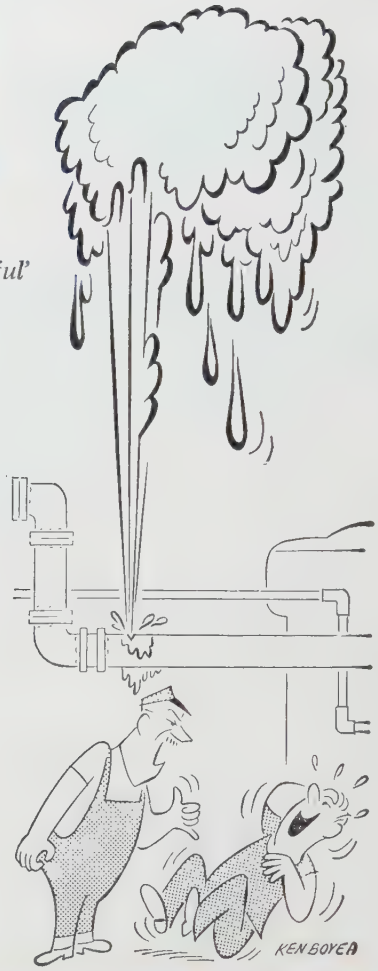


# What to do when corrosion sends costs sky high

No one can afford ruined equipment, endless repairs, and plant shut-downs caused by corrosion. And you *shouldn't* afford *over*-design and too-fancy equipment. Ace takes you right down the middle . . . a wide choice of chemical-resistant pipe, pumps, valves, tanks, etc. Best for the money anywhere . . . backed by 108 years' experience.

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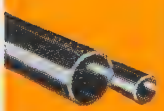

Best non-metallic pipe anywhere for *hot* chemicals to 275°F. Also handles tough organics. Rigid, tough nitrile. Pipe and fittings to 8". *Bul. 96A.*

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1001 uses. Nontoxic, odorless, tasteless, sterilizable, flexible tubing. Excellent for chemicals, foods, and for lab or machine lines. ⅛ to 1¼". *Bul. 66.*

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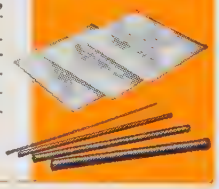

Special equipment often can be machined, punched or welded of standard plastic or hard rubber sheet, rod or tubing. Write for details today.

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70°F. Paraffin waxes are not usually flexible until well above 70°F. Results are recorded:

1. O.K.—completely flexible—good load throughout.
2. Degrees of angular deflection at break.
3. Fair—completely flexible, but does not maintain good load throughout test.
4. Poor—similar to 3, but load maintained is practically nil.

The test does not simulate flexure of wax in commercial applications of thin films. Their value is in following production trends.

### *Gloss and Gloss Retention*

For almost all wax coating to be seen by a customer, gloss is an important factor. Most fully refined paraffin waxes can be made to produce a good gloss by varying wax-bath temperature, chill-bath temperature, and speed of chilling. However, on aging many waxes show poor gloss retention. Fast chilling produces small crystals and good gloss. Upon aging the crystals in some wax reorient themselves to decrease gloss. To test this characteristic in the laboratory, we coat breadwrap paper at 30°F. above melt point of wax, and chill in ice water at about 40 to 45°F. The initial gloss is rated good, fair, or poor. The strips are then conditioned for two weeks at 70° and 50% R.H. and rated for gloss retention. Study is still underway to develop more accurate measurement by mechanical means involving light reflected from waxed surfaces. At this time, visual comparisons on gloss are as reliable and reproducible as mechanical methods.

Gloss retention is related to composition. Some isoparaffins present during manufacture of broad melting point range paraffin waxes are detrimental to gloss. Larger amounts of microcrystalline wax do not produce a dull finish. Polyethylene improves gloss and gloss retention. To plasticize the polyethylene, large amounts of microcrystalline wax are therefore used.

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# ...packages coated with A-C Polyethylene

...heat treatment using A-C® Polyethylene ...ped by Semet-Solvay imparts *super* high ...o waxed paperboard . . . lets you dispense ...verwrapping in many cases. It's ideal for ... food and ice cream packages . . . butter ...eo . . . bread wrappers.

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### *Viscosity*

Viscosity of petroleum waxes is measured at 210°F. Paraffin waxes have a viscosity of about 36 to 40 seconds and microcrystalline waxes 65 to 130 seconds.

The main significance of viscosity is the ability of the wax to penetrate paper. Since the viscosity will change with temperature, temperature control for regulating penetration becomes apparent. For a typical microcrystalline wax the viscosity might increase from 90 to 142 seconds as the temperature is reduced from 210 to 180°F.

### *Hardness*

In general, hardness is desired in paraffin waxes to provide good gloss, scuff resistance, and resist blocking. For some uses, hardness is also desired in microcrystalline waxes to offset blocking.

Needle penetration (ASTM Method D-1321) is used to define hardness of microcrystalline waxes. The harder the wax, the lower will be its penetration value. Crude scale waxes are always softer than fully refined waxes because of the increased oil content. Likewise, microcrystalline waxes will have a higher penetration.

Abraham Consistometer is used for measuring hardness of paraffin waxes. It is expressed as the cube root of the force in grams necessary to push a plunger with a circular face of 1 sq. cm. through the wax at the rate of 1 cm. per min. Thus, the harder the wax, the higher is the number. The measurement is usually at 105°F.

### *Tensile Strength*

This measurement is an indication of the cohesiveness of wax and is conducted in a more or less standard manner. Values are usually expressed as the readings indicated by the tensile tester, and show the force required to break a briquette with a cross-sectional area of $^1/_4$ sq. in. These values must be multiplied by four to express tensile strengths in pounds per square inch.

Many users of paraffin waxes believe that tensile strength is one of the main criteria of good quality. This is true only of low tensile strengths which are related to high oil contents. Other than this there is only a limited relationship with most performance characteristics. One of these is sealing strength, but even here differences in tensile strengths of 20 to 30 p.s.i. may have little significance unless considered in conjunction with other characteristics.

### *Greaseproofness*

This property is related to solubility and is a function of grease or fat in wax. Microcrystalline waxes and paraffin waxes differ very little in their ability to impart grease resistance at lower temperatures. However, at elevated temperatures there is a significant difference, as illustrated by the percentage solubility of waxes in peanut or olive oil at various temperatures.

| *Wax* | *Temperature, °F* 70 | 100 | 125 |
|---|---|---|---|
| Paraffin | 0.95 | 7.2 | 54 |
| Microcrystalline | 0.09 | 0.53 | 2.7 |

### *Stability to Oxidation*

When petroleum waxes are subjected to oxidizing conditions, portions of them are converted to more reactive chemicals, such as alcohols, peroxides, aldehydes, ketones, and acids. These materials undergo further reactions so that the mechanism of oxidation is quite complex. Oxidation is evidenced by a darkening of the wax, the development of a rancid odor (caused by acid formation), loss of strength, and a loss of moistureproofing value. All of these are deleterious, and, for that reason, oxidation of petroleum waxes should be guarded against at all times.

Oxidation results from a chemical combination of the hydrocarbon waxes and oxygen of the air. It is obviously accelerated by high temperatures and long times of exposure to air. Similarly large surface areas of exposure and aeration of molten wax permit more of it to come in contact with the air. All of these adverse service conditions should therefore be held to a minimum.

Metals have a catalytic action in accelerating oxidation of waxes, and the rate of oxidation is dependent to a large degree upon the area of metal coming in contact with the wax, but to an even greater degree upon the nature of the metal itself. Extensive tests have shown that copper and copper-bearing metals are powerful catalysts, and that carbon steel has the least effect upon oxidation. Between these extremes are nickel, chromium, aluminum, and stainless steel, Equipment for handling molten petroleum waxes should therefore be constructed of carbon steel wherever possible. This is particularly true of the heating coils where temperatures are at their highest point.

| *Storage temperature, °F.* | *Days of acceptable odor level* |
|---|---|
| 150 | 25 |
| 160 | 15 |
| 180 | 6 |
| 200 | 2 |
| 220 | $^1/_2$ |

Once oxidation has taken place, a reaction occurs between the acidic constituents produced, and metals of the equipment, leading to the formation of soluble metallic soaps. These soaps have a more pronounced catalytic action than bare metal itself, primarily because the soaps have become dispersed throughout the body of the molten wax. For this reason, and because of the dark sludges which are formed during oxidation, it is essential that equipment handling molten waxes be given periodic cleanings. These cleansings should be made whenever there is any indication of excessive rancidity or abnormal sludge formation in the wax bath. Microcrystalline waxes are heavier and higher boiling than paraffin waxes, and bear the same relationship to them that exists between heavy lubricants and light oils. They, therefore, are far more resistant to oxidation and can withstand more severe handling conditions. Some care should be exercised in handling molten microcrystalline waxes, but this need not be as great as when it is paraffin waxes that are in use. An indication of the rate of paraffin wax deterioration with increased temperatures illustrates the need for care in storage and handling, and the desirability of incorporating oxidation inhibitors at the refinery.

Presented at the St. Louis Section of TAPPI, St. Louis, Mo., April 26, 1960.

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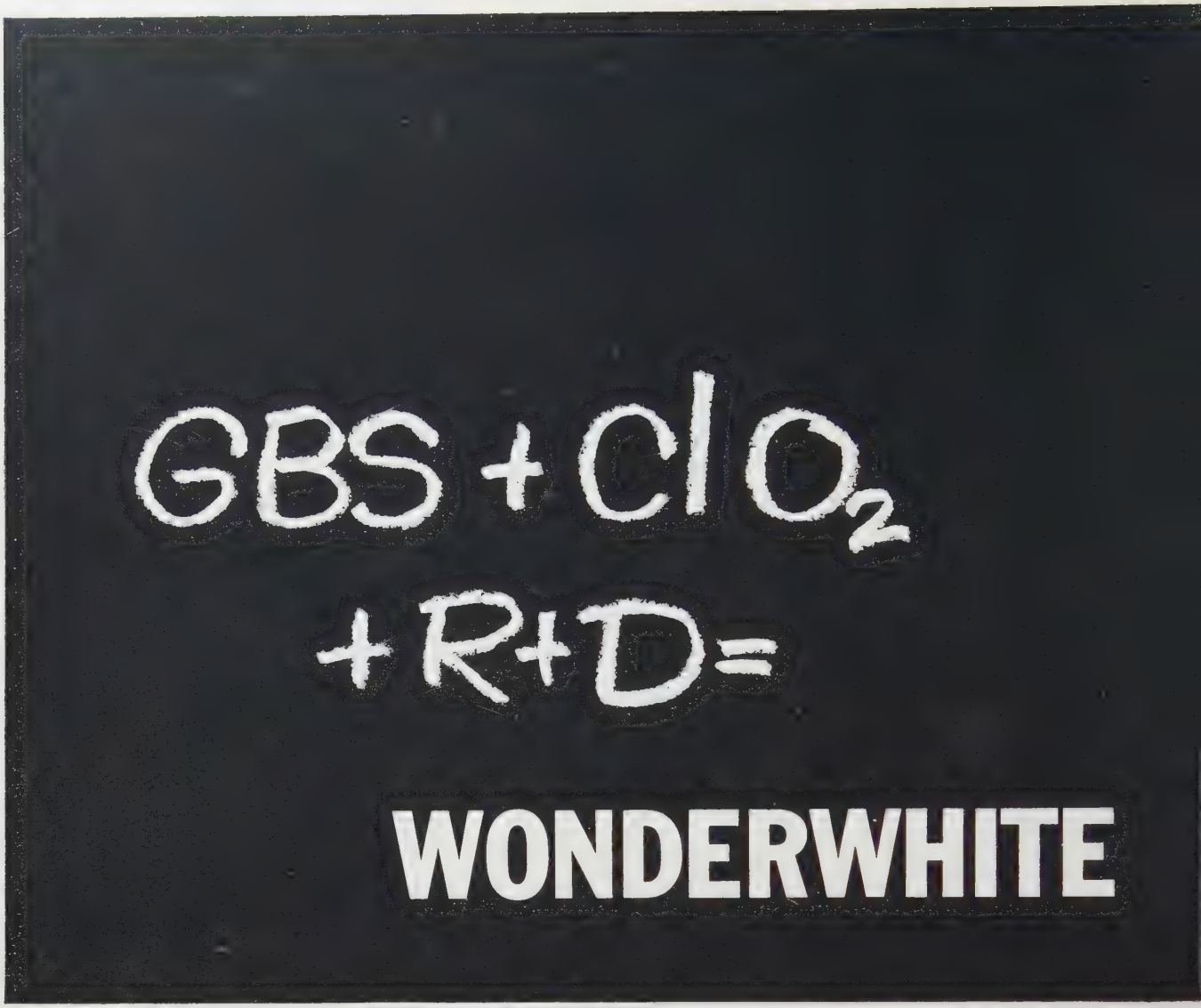


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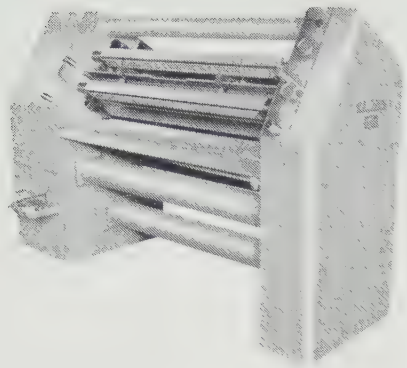
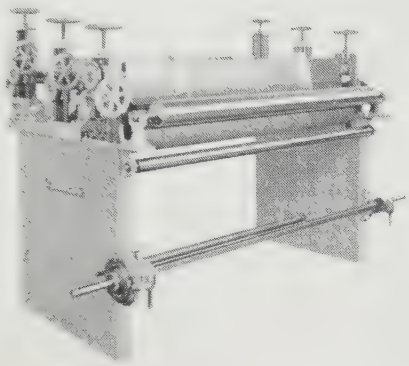
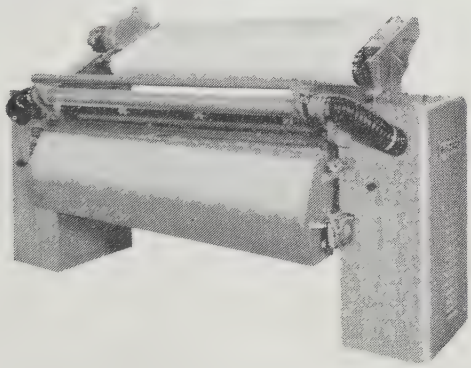


Reverse Roll Coater



Sequential Knife Coater



Microjet Air Blade Coater

# WALDRON ADVANCE DESIGN *standard* COATERS SOLVE MANY *special* COATING PROBLEMS

As manufacturers of coating machines for the web processing industry for over a century, Waldron engineers have been called upon to solve innumerable coating problems. The Waldron "standard" line of advanced design coating like those illustrated reflects this vast experience.

These coaters are applied to solve most coating problems. These standard units can be *customized* to meet your "special" requirements.

Complete coating lines including web handling equipment with our Ross Division convection dryers are engineered by Waldron as a single responsible source of supply.

Our engineers are ready to work with you to select the equipment, and our extensive pilot plant facilities are at your disposal for tests.

Write us describing your coating needs. We will be happy to advise how a "standard" Waldron coater can solve your "special" coating problems.

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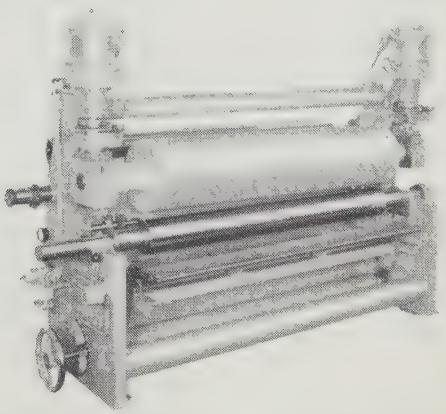
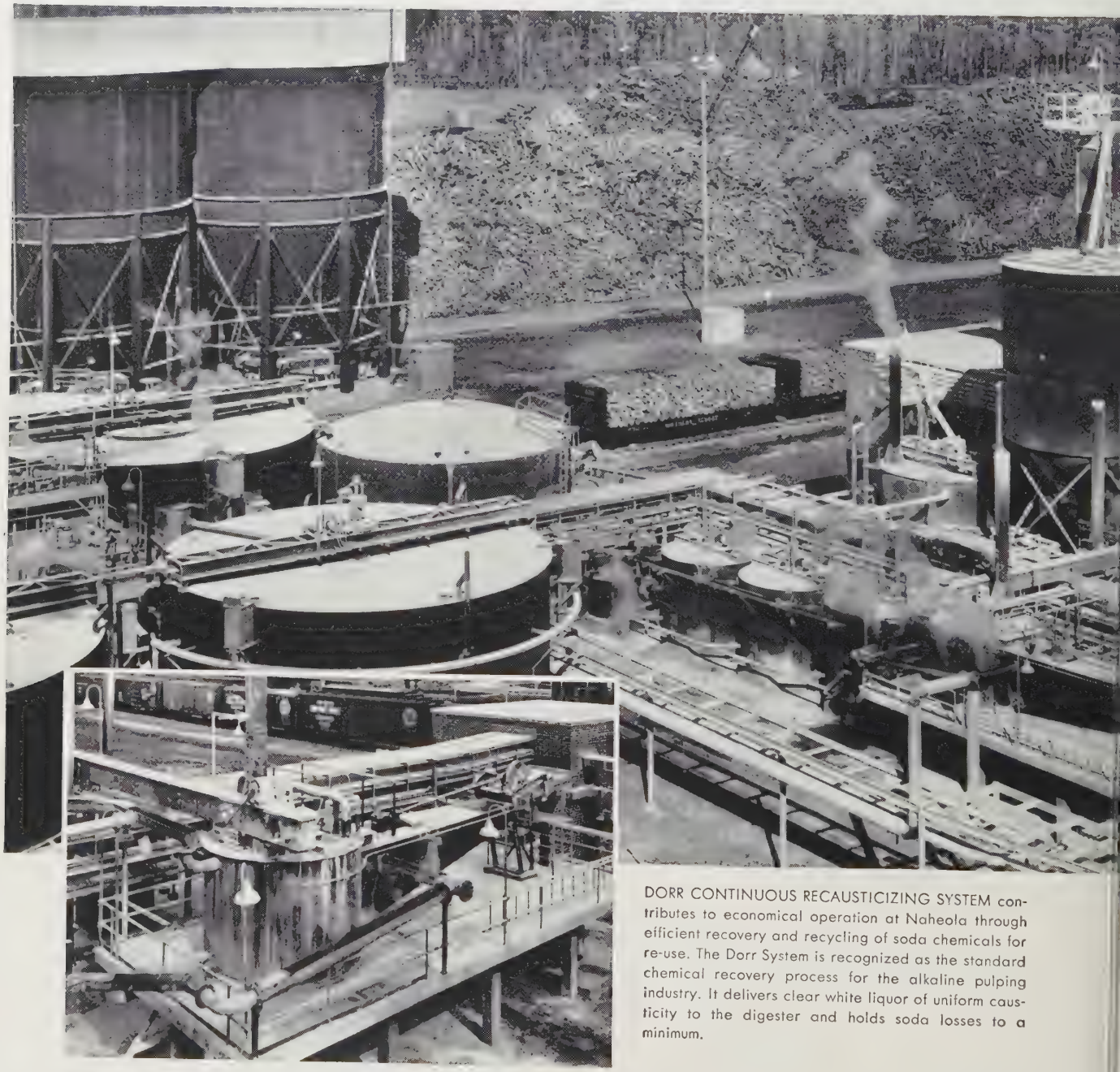


Single Color Gravure Printer

WM-360

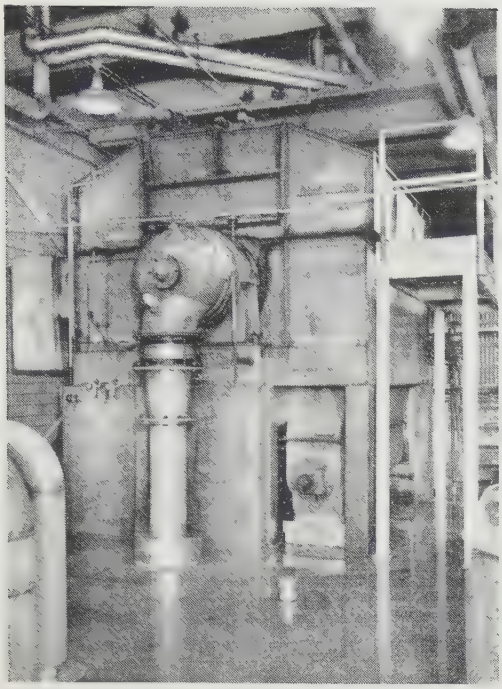
*How Dorr-Oliver equipment helps*

# MARATHON SOUTHERN GET MAXIMUM SAVINGS in new Naheola (Ala.) mill



DORR CONTINUOUS RECAUSTICIZING SYSTEM contributes to economical operation at Naheola through efficient recovery and recycling of soda chemicals for re-use. The Dorr System is recognized as the standard chemical recovery process for the alkaline pulping industry. It delivers clear white liquor of uniform causticity to the digester and holds soda losses to a minimum.

DORRCO SLAKER, installed at the lime slaking station of the recausticizing system, slakes and blends makeup lime with the overflow from the Primary Slaker, at the same time washing and removing grit.

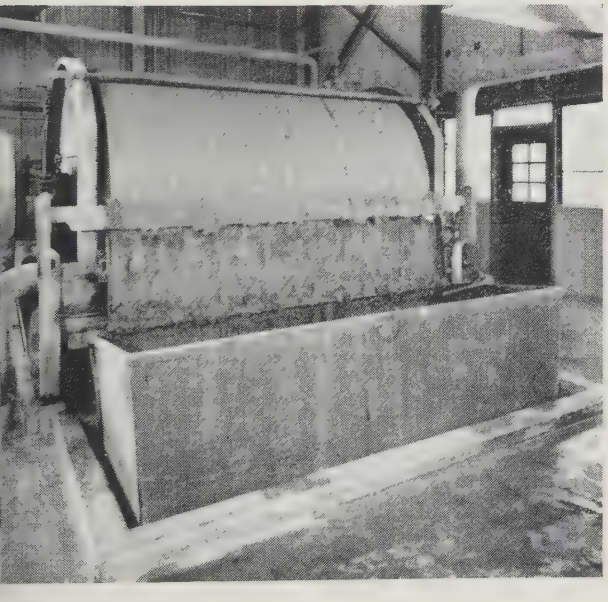


AMERICAN DISC-TYPE SAVEALLS (2 installed), supplied by Dorr-Oliver, provide for maximum recovery of pulp fibers from white water. Features include large filter area and capacity with minimum floor space and continuous, fully automatic operation.

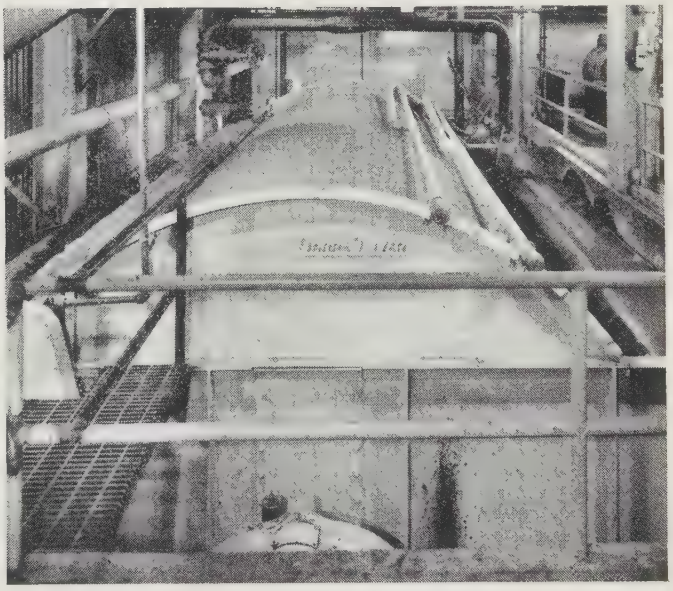
Maximum savings all along the line dominated the thinking of Marathon Southern Corporation when it planned its multi-million-dollar pulp, paper and converting facility, now in operation at Naheola, Alabama.

The basic operating economies inherent in the choice of site—abundant raw materials, a good labor supply, convenient transportation and proximity to potential markets—are enhanced by modern plant design and equipment. Contributing to high production, maximum utilization of materials and savings in operating costs are the examples of advanced Dorr-Oliver engineering shown on these pages. The success of Dorr-Oliver equipment is based on more than 35 years of experience in serving the pulp and paper industry.

For more information on this and other equipment, write to Dorr-Oliver Incorporated, Stamford, Connecticut. Better still, let us send a Dorr-Oliver engineer to discuss your specific problems.



OLIVER LIME MUD FILTER provides a high capacity, low maintenance unit for maximum recovery of mud for reburning. Evidence of the large scale of Naheola operations is the fact that a total of 100 tons of lime are recovered daily.



OLIVER 11'6" x 20' VALVELESS DECKER installed in screen room thickens stock after washing and screening. Valveless design operates efficiently on free pulps and results in reduced liquor and pulp pumping costs.

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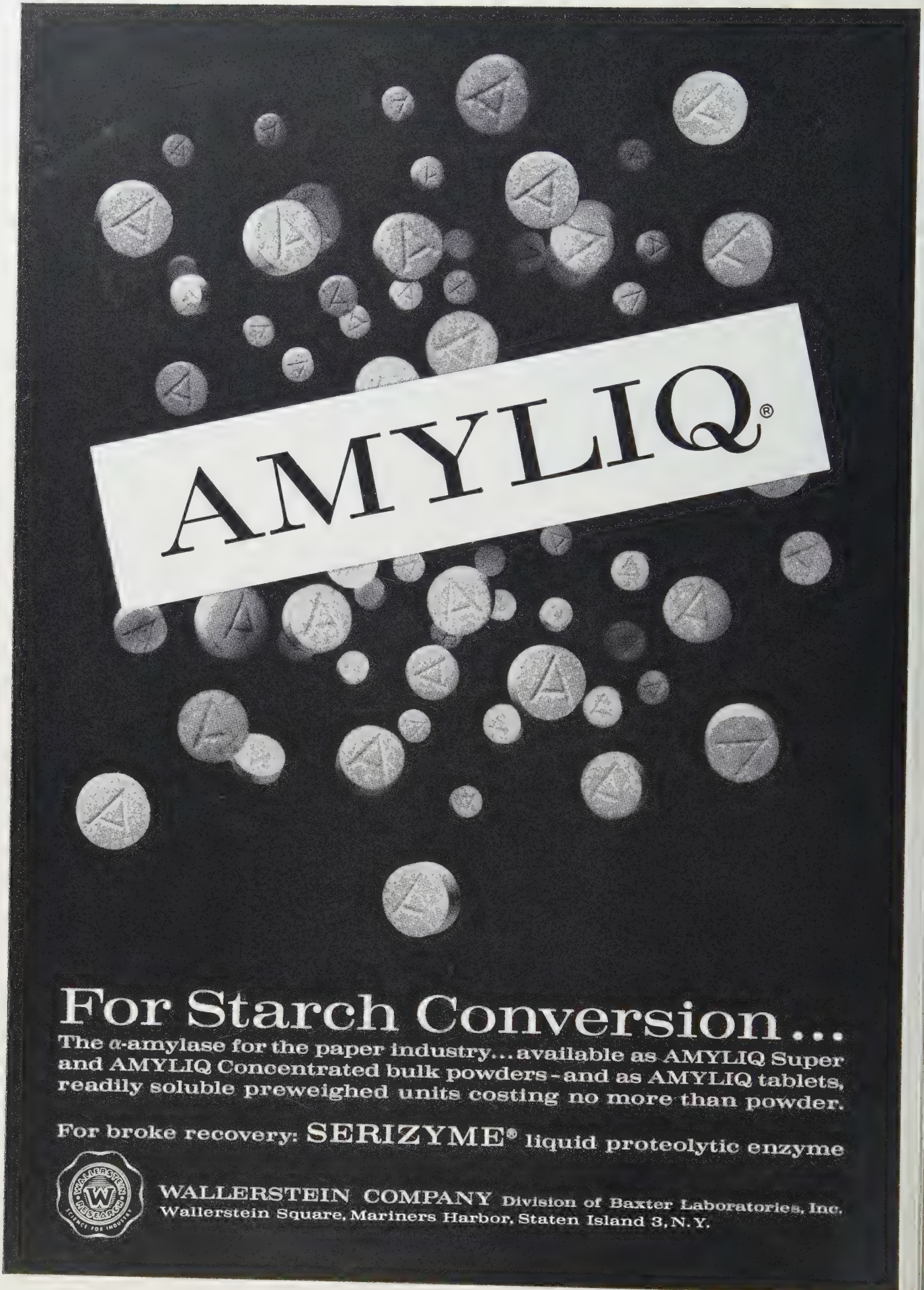
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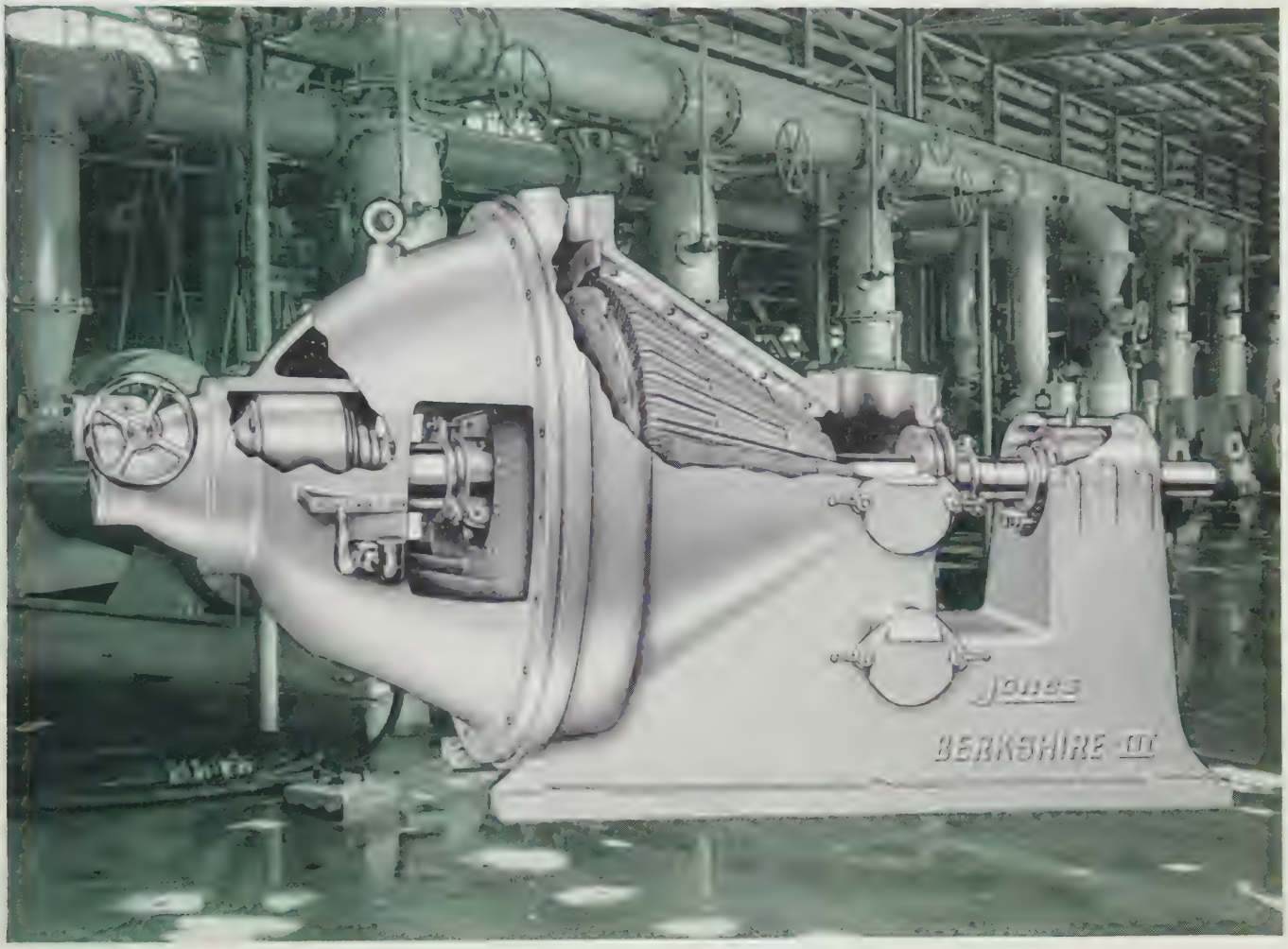

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Precision built in the Jones tradition, new Berkshire wide angle Refiners develop maximum fibre strength with minimum fines formation. The economical Berkshire, with proper tackle, is highly successful not only in hot stock refining but also in the development of both soft and hard wood pulps. In addition, Jones Berkshires offer several important operating advantages. With only three major components—shell, plug and head—compared to seven in most competitive machines, better alignment, longer wear and more uniform refining are assured.

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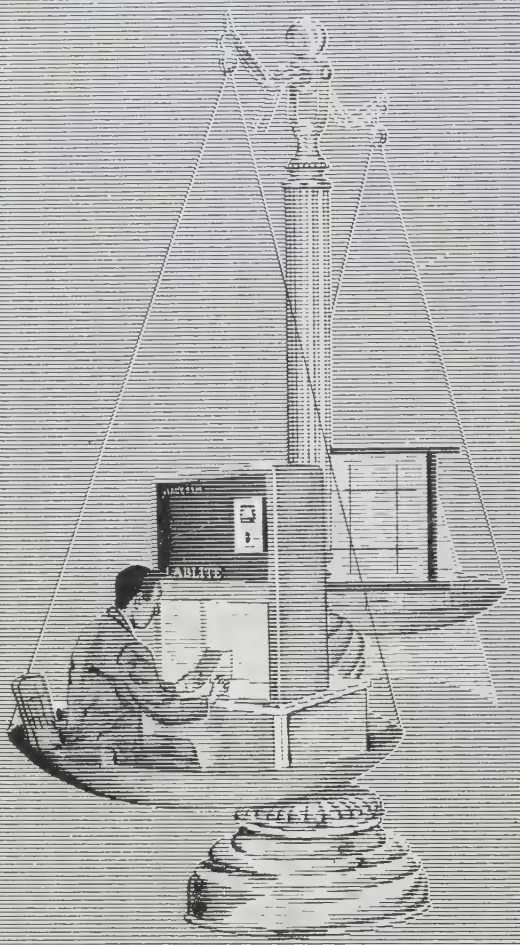

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3. Night shift really works in the dark.
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Solar Blue UTN 58-6692
Solar Blue UMN 57-6692
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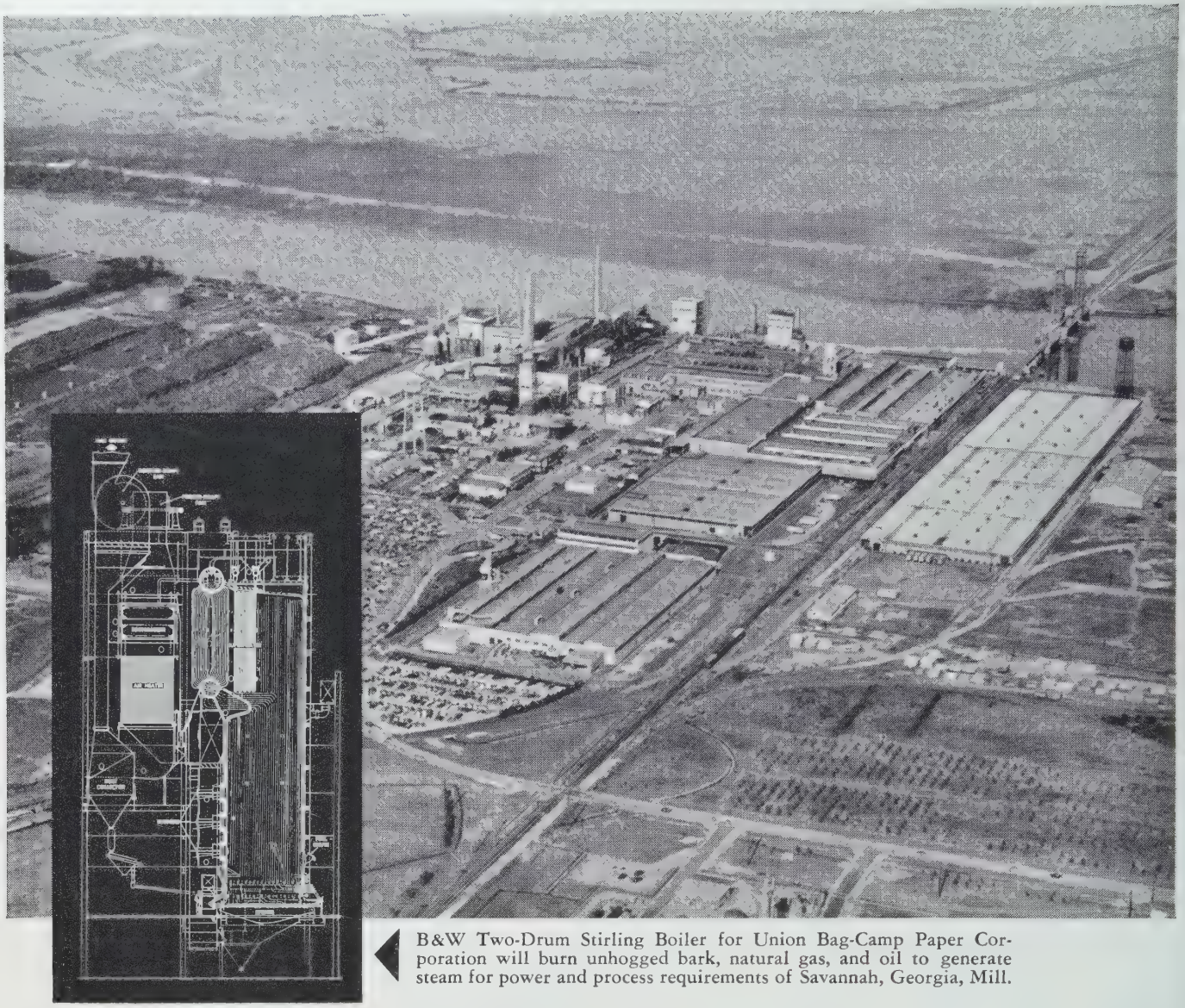

B&W Two-Drum Stirling Boiler for Union Bag-Camp Paper Corporation will burn unhogged bark, natural gas, and oil to generate steam for power and process requirements of Savannah, Georgia, Mill.

# Why America's Largest Bark-Burning Boiler is a B&W Boiler

The highest rated bark-burning boiler ever built will soon be generating 550,000 pounds of steam per hour at Union Bag-Camp Paper Corporation's huge mill at Savannah, Georgia. It will burn unhogged bark as a primary fuel but can also be fired with natural gas or oil—singly or in combination with the other fuels. The unit has a design pressure of 1250 psi at the superheater outlet and will operate at 950 F.

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Chemicals—Pigments—Metals Division
Baltimore 26, Maryland

*(This advertisement is printed on paper stock containing Glidden ZOPAQUE Titanium Dioxide.)*

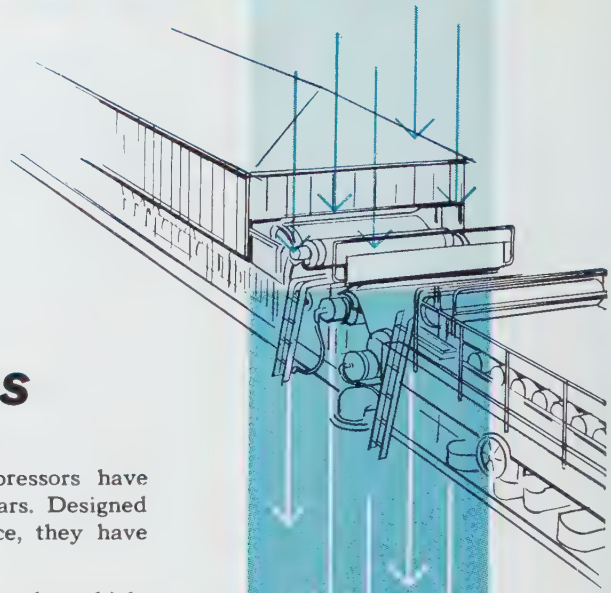
## for paper mill

# VACUUM SERVICE

## only the I-R

# Axi-compressor

## offers all these cost-saving advantages



**Proven Reliability.** Thousands of horsepower of Axi-compressors have been operating successfully in vacuum service for many years. Designed for higher pressures and heavier loads in compressor service, they have extra, reserve strength on *vacuum* service.

**Compact Construction.** Smaller in size than any other heavy-duty, high-capacity vacuum pumps, they are often the *only* units that can be installed in available space to increase the production of existing equipment.

**Low Installation Costs.** Axi-vacuum pumps can be mounted on smaller foundations and are more economical to transport and install than any other vacuum units in their pressure and capacity range.

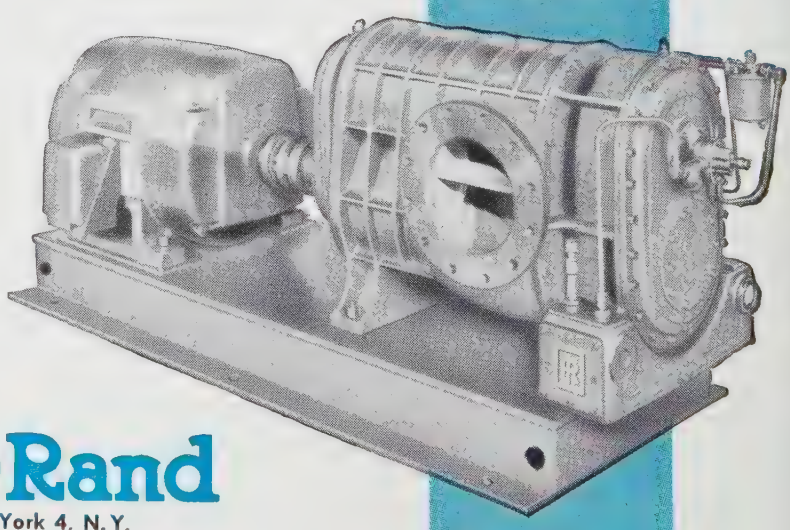
**Low Power Costs.** Designed for high operating efficiency and direct connection to higher speed motors, they save on both operating cost and first cost of drive equipment.

**Low Seal Water Requirements.** Less than 1 gpm per 1000 cfm capacity provides ample seal for vacuums of 12″ Hg and higher. Lower vacuums require no seal water at all.

**Greater Versatility.** Any Axi-vacuum pump can provide a wide range of vacuum simply by changing the driver horse power. A unit installed for high vacuum, may be used on lower vacuum services and still maintain its high operating efficiency.

**Low Maintenance.** The two dynamically balanced rotor elements operate with no metal-to-metal contact, virtually eliminating mechanical wear.

**Wide Range of Sizes.** The large number of sizes permits meeting practically all vacuum requirements from a standard line. Each unit can be selected for actual inlet conditions, and changes in inlet temperature have little effect on capacity. Axi-compressors are available in capacities to 12,000 cfm for vacuums to 22″ Hg single stage and 26″ Hg two stage. Ask your I-R representative for complete information or write for bulletin 11,004.

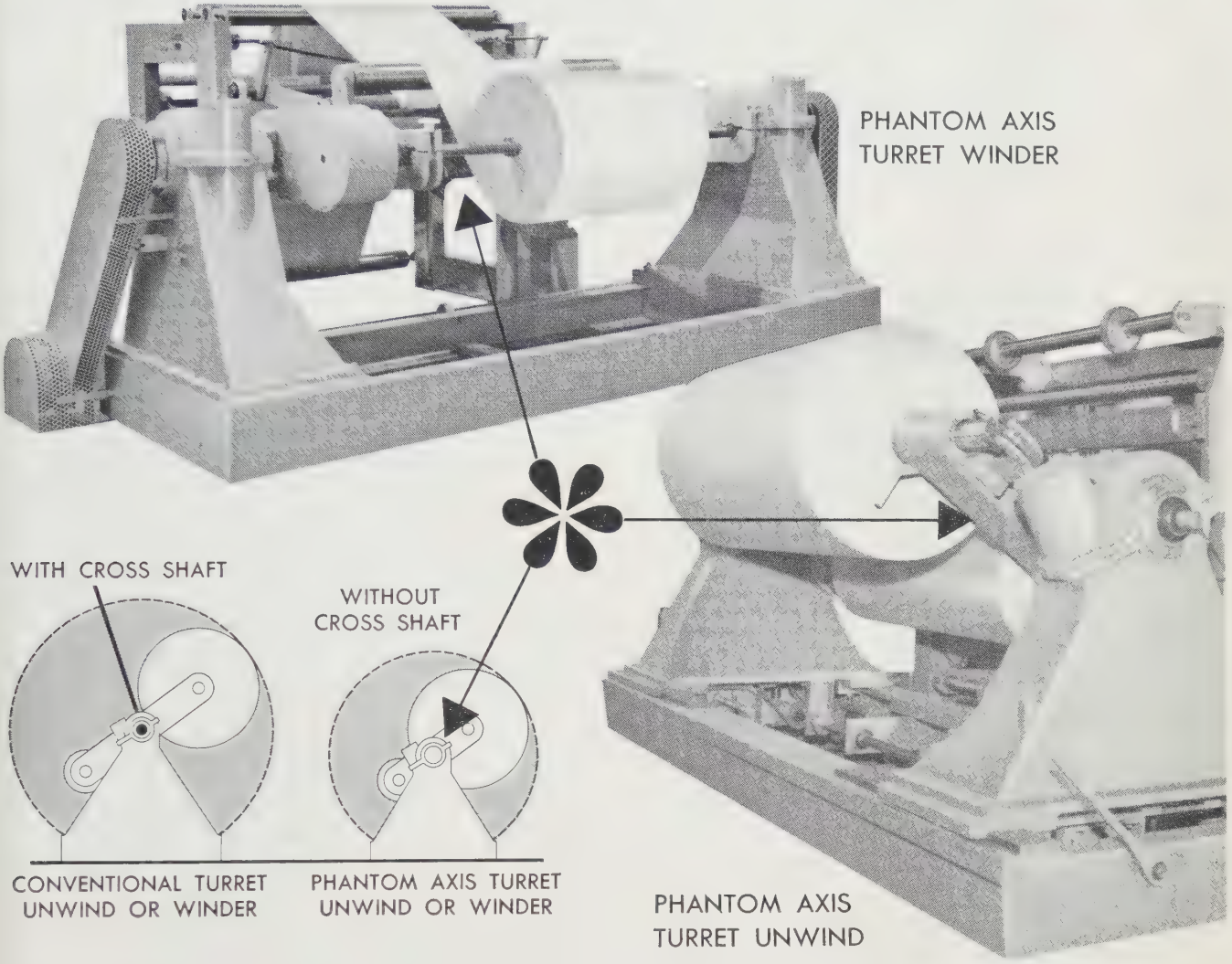


Ingersoll-Rand

17-913 11 Broadway, New York 4, N.Y.

PUMPS • CENTRIFUGAL & RECIPROCATING COMPRESSORS • DIESEL ENGINES • AIR & ELECTRIC TOOLS • TURBO BLOWERS • STEAM CONDENSERS

# IT'S WHAT'S NOT THERE THAT COUNTS*




Egan's revolutionary Phantom Axis Turret Unwinds and Winders *eliminate* the center cross shaft for greater roll diameters and more compact overall design. In addition, these units require less overhead and floor space for installation (see drawing).

The more compact design also assures greater rigidity and better operation at high speeds. Phantom Axis Unwinds and Winders are engineered to permit speeds in excess of 1000 fpm; are available in web widths through 120", and include power rotation of the turret and knife cut-off as standard features. Air chucking of cores or shafts is available at the customer's option.

## ADDITIONAL FEATURES

PHANTOM AXIS UNWIND: Automatic or manual side shifting; provision for splicing with either inside or outside of web up (optional); flying splices at full machine speed; pneumatic constant tension system (optional).

PHANTOM AXIS WINDER: Side shifting available (automatic or manual); constant or tapered tension; smooth transfers at full machine speed with unique single motor design.

Egan

CABLE ADDRESS: EGANCO—SOMERVILLE (NJER)

**FRANK W. EGAN & COMPANY**
**SOMERVILLE, NEW JERSEY**

MANUFACTURERS OF PROCESSING MACHINERY FOR PAPER, FILM & FOIL, AIR DRYING SYSTEMS; ROTOGRAVURE PRINTING PRESSES; PLASTICS EXTRUDERS & ACCESSORIES; TEXTILE FINISHING MACHINERY.

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ACHARD-PICARD, REMY & CIE, 36 RUE D'ENGHIEN X, PARIS, FRANCE
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CHUGAI BOYEKI CO., KATO BUILDING, TOKYO, JAPAN
M. H. GOTTFRIED, AVENIDA 16 DE SEPTIEMBRE 10-304, MEXICO, D. F.

Write for complete information.

# How Du Pont brighter pulp...save

## Mechanical pulp bleaching...

*A combination of peroxides can save up to $1.25 a ton over a hydrogen peroxide treatment.*

Over 95% of all groundwood bleacheries have found that a combination of hydrogen and sodium peroxides cuts bleaching costs up to $1.25 a ton. The reason—combination formulas eliminate the use of caustic soda.

How is this possible? Because of the bleaching chemistry involved. When hydrogen peroxide is used alone, substantial quantities of caustic soda must be added to assure effective bleaching. But when sodium peroxide is part of the formula, caustic soda is formed and additional quantities aren't needed. When caustic limits of this solution are reached, hydrogen peroxide is added to complete the balance and the bleaching formula is now ready to use.

The charts below show the savings possible in a one-stage tower bleaching process when a combination of peroxides is used instead of a single hydrogen peroxide: For normal brightness, the saving runs from $.90 to $1.00 a ton; for premium brightness, $1.15 to $1.25 a ton.

You can obtain cold soda pulp and groundwood pulp brightness as high as 75 by this method. Cold soda pulp can be bleached in the refiner in absence of a bleaching tower with brightness gains up to 20 points.

For further information, get in touch with your Du Pont Representative listed at right.

EXAMPLE #1

**ONE-STAGE TOWER PROCESS FOR NORMAL BRIGHTNESS**

**A. Using combination of peroxides**

5.0% silicate
1.2% "Solozone" sodium peroxide
0.7% "Albone" 50 hydrogen peroxide

**B. Using one peroxide only**

5.0% silicate
1.2% NaOH
1.7% "Albone" 50 hydrogen peroxide

**SAVINGS OF $.90 TO $1.00 PER TON BY USING COMBINATION OF PEROXIDES**

EXAMPLE #2

**ONE-STAGE TOWER PROCESS FOR PREMIUM BRIGHTNESS**

**A. Using combination of peroxides**

5.0% silicate
1.5% "Solozone" sodium peroxide
1.25% "Albone" 50 hydrogen peroxide

**B. Using one peroxide only**

5.0% silicate
1.5% NaOH
2.5% "Albone" 50 hydrogen peroxide

**SAVINGS OF $1.15 TO $1.25 PER TON BY USING COMBINATION OF PEROXIDES**

# Peroxides give you you up to $1.25 a ton!

## Chemical pulp bleaching...

*Peroxides—alone or in combination—give brightness up to 92 with excellent stability.*

Mills throughout the country are finding that peroxides, alone or in combination, can give chemical pulp high brightness stability—without significant decrease in pulp strength or yield.

**IN KRAFT BLEACHING,** a five-stage process is producing outstanding results for a number of mills, among them a southern papermaker now producing over 100,000 tons of high brightness pulp annually. This process combines the best advantages of three bleaching agents—hypochlorite, chlorine dioxide and peroxide—to give brightnesses up to 90 with excellent brightness stability.

**IN SULFITE BLEACHING,** three peroxide processes are proving successful—a single-stage peroxide process which brightens pulp up to 75; a two-stage hypochlorite-peroxide process which brightens up to 86; a four-stage chlorine-caustic-hypochlorite-peroxide process which brightens up to 92. For information, call your Du Pont Representative listed below.

**TECHNICAL SERVICE FOR YOU . . .** Peroxides have a powerful bleaching action that produces high brightness pulp with excellent brightness stability. But it takes skill and experience to use peroxides efficiently. With Du Pont "Albone" hydrogen peroxide and "Solozone" sodium peroxide, you get the most authoritative advice and service available . . . from the manufacturer of *both* products.

Du Pont specialists can give you practical bleaching formulas for groundwood, cold soda, kraft and sulfite. They'll help you set up your bleaching operation, train operators, and check frequently to make sure your bleaching quality stays high and costs stay low.

Call your Du Pont representative listed below; he'll be glad to start a program to help you determine the advantages of Du Pont peroxides in your mill. Or write: Du Pont, Electrochemicals Department, Peroxygen Products Division, Wilmington 98, Delaware.

**MIDWEST AREA**
W. L. Liike, Chicago, Ill. • INdependence 3-7250

**WEST COAST AREA**
P. E. Kiefer, Portland, Oregon • CApitol 7-1281

**NEW YORK & BOSTON AREA**
C. R. Lombard, NewYork, N.Y. • LOngacre 3-6440

**SOUTHERN AREA**
R.W. Hammond, Charlotte, N.C. • FRanklin 5-5561

Or call: N. J. Stalter, Wilmington, Del. • PRospect 4-4698

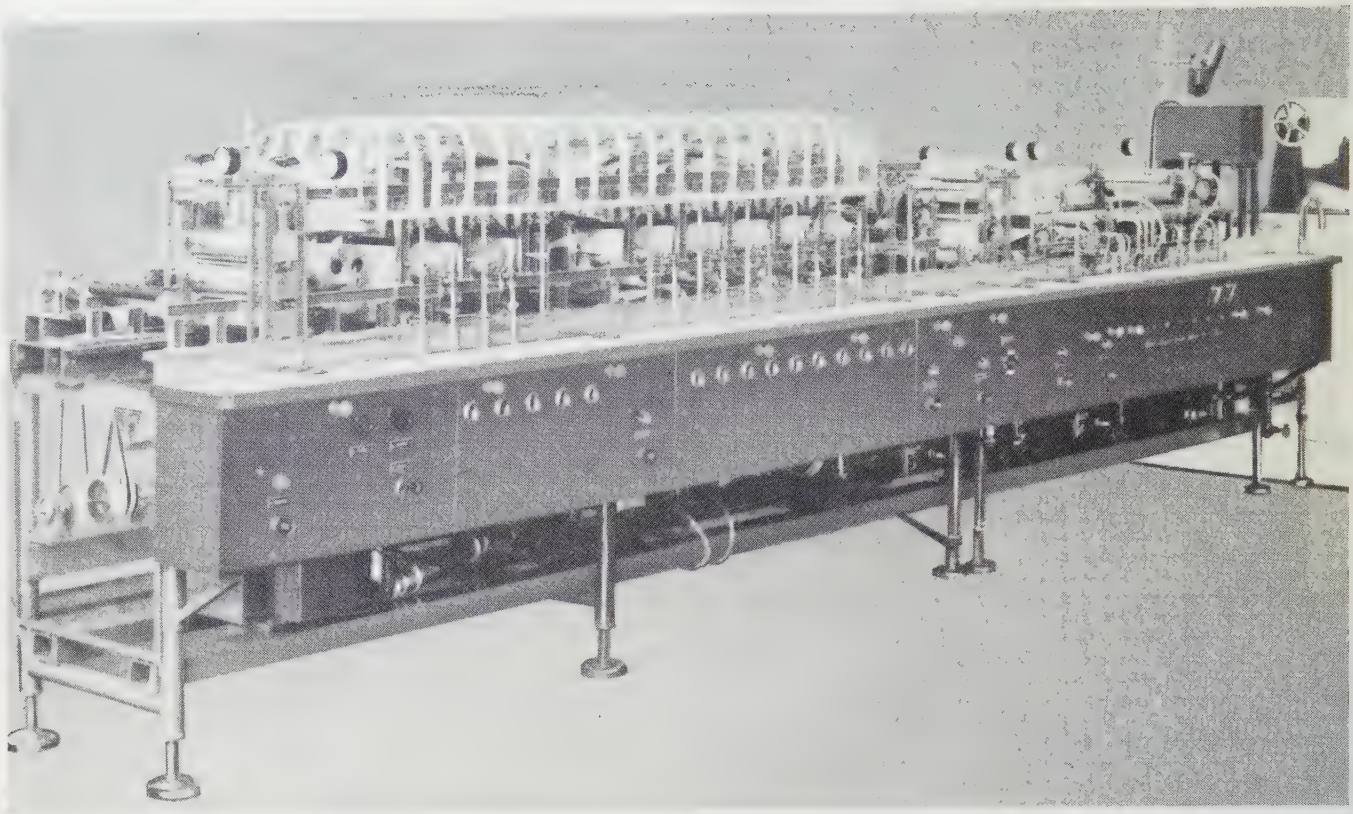
**DU PONT PEROXIDES**

**ALBONE®** hydrogen peroxide

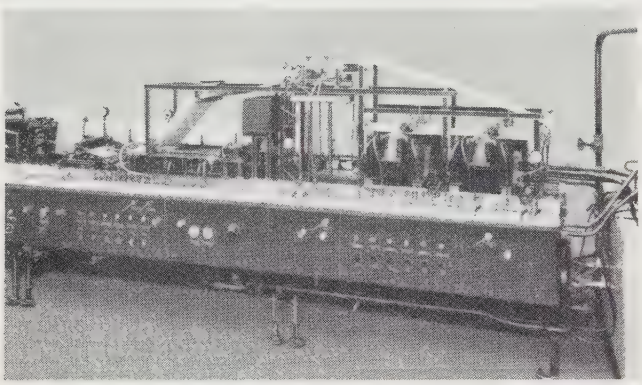
DU PONT REG. U. S. PAT. OFF.

**SOLOZONE®** sodium peroxide

BETTER THINGS FOR BETTER LIVING . . . *THROUGH CHEMISTRY*



# NEW P&W MIDGET FOURDRINIER PAPER MACHINE



*The standard P&W Midget Fourdrinier model can also be operated in combination with miniature cylinder molds to provide more versatile sheet formation experiments.*

**Present users of the P&W Midget Fourdrinier Paper Machine include:** West Virginia Pulp & Paper Co. • U. S. Dept. of Agriculture—Peoria Lab • Nat'l Bureau of Standards—Washington • Hurlburt Paper Company • E. I. Dupont de Nemours & Co., Inc. • R. J. Reynolds Tobacco Company • Forest Products Lab.—Philippines • Forest Products Lab.—Pakistan • U. S. Naval Laboratory.

## Permits Precise Small-Scale Test Runs of a Wide Variety of Paper Formulations

As little as 5 lbs. of stock is all it takes to start the P&W Midget Fourdrinier making a continuous sheet of paper which can be successfully duplicated on a full-size paper machine. Such test runs effect a significant saving in raw materials, manpower and production machine time.

The P&W Midget Fourdrinier is also of special interest and value to educational institutions and technical laboratories. It is safe, clean and easy to operate. One man only is needed to adjust temperatures and pressures for a wide variety of paper making experiments.

### SPECIFICATIONS

*Paper Quality*—Comparable to full-size Fourdrinier products
*Weight of paper*—12-120 lbs.
*Output*—up to 3.3 lb./hr.
*Speed*—2-8 ft./min.
*Overall length*—14 ft.
*Overall width*—33 in.
*Working width*—9 in.

*Write for full descriptive literature.*

**THE PARSONS & WHITTEMORE / LYDDON ORGANIZATION**

*World leaders in the development of pulp and paper mills for the use of local fibers*

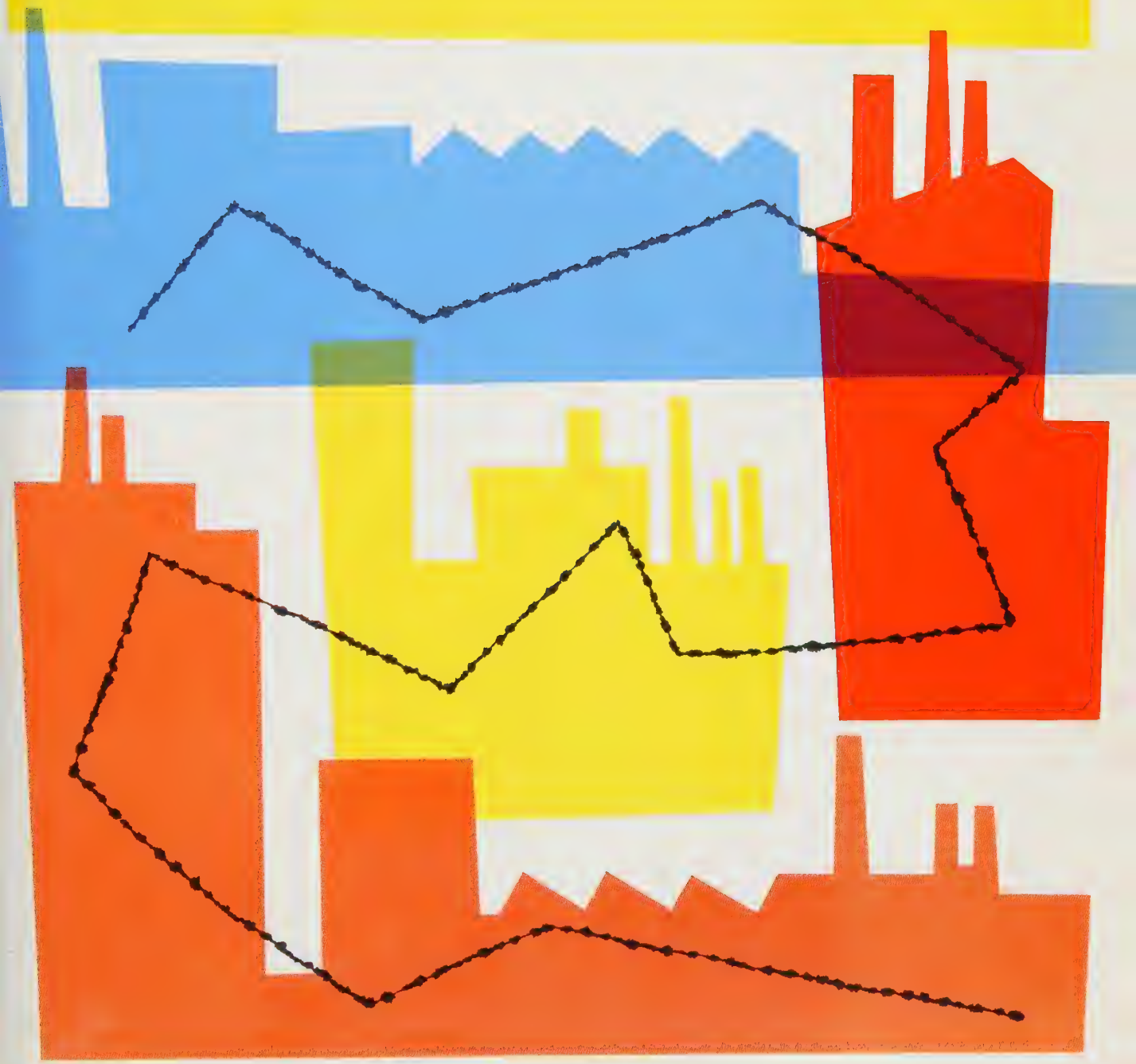
18-19 Savile Row, London W. 1, England

5 Rue Jean Mermoz, Paris 8°, France

250 Park Avenue, New York 17, N. Y.

**LET YOUR APPLETON MAN TAKE A FRESH LOOK AT YOUR FELT APPLICATION AND PERFORMANCE PROBLEMS.** It can be a rewarding experience—it has been for others. By working with our laboratory research men, felt designers and experienced production people, he can bring you a custom designed application to improve felt performance and life. What better way to increase production and cut costs (has a nice effect on profits, too). Ask him to take a look-see soon! You'll be glad you did!

**AP-PLY FELTS**
Appleton Woolen Mills
Working With The Paper Industry
Appleton, Wisconsin



# Developed Specifically for Boxboard Coatings

# COLTON FLEXAC 1256

PROVIDES HIGHER SOLID BASE FOR GREATER COATING WEIGHT... REDUCES COSTS

You can improve the quality of boxboard coatings in every important way and reduce your costs with Colton Flexac 1256.

Flexac 1256, a homopolymer polyvinyl acetate emulsion, has a higher solid base . . . therefore, less moisture to evaporate. Too, because of its higher solid base, less Flexac 1256 is required for a specified weight.

Coatings made with Flexac 1256 are highly resistant to light and heat. They maintain a high brightness; whites stay permanently white.

Low odor level, superior printability, and exceptional pick resistance characterize this Colton synthetic polymer.

Boxboard coatings formulated with Flexac 1256 are now being used successfully in commercial machine runs.

If boxboard is your business you are, of course, interested in anything that will upgrade the quality of your product and at the same time push back your costs. Flexac 1256 developed specifically for board coatings is your answer.

*Write now for complete data.*

COLTON

**COLTON CHEMICAL COMPANY**

A Division of Air Reduction Company, Incorporated • 1747 Chester Avenue, Cleveland 14, Ohio
Sales Offices and Warehouse Facilities Throughout U.S. • Export: Airco Company, International, New York 17, N.Y.

*AT THE FRONTIERS OF PROGRESS YOU'LL FIND . . .*

AIR REDUCTION PRODUCT

# the condemned ate a hearty meal!

And a justly-deserved fate, too!

Especially when the culprit's name might be *Aerobacter aerogenes* . . . or *Bacillus mycoides* . . . or a half dozen other trouble-makers that are responsible for slime problems in paper mills.

Helping to solve slime problems *effectively* through a planned program of microbiological control is *just one* of the many services offered by Betz Laboratories. For over 35 years, Betz has provided specialized consulting engineering service to the paper industry, including the use and application of slime control agents, pitch dispersers, anti-scaling agents, retention aids, filming amines, corrosion inhibitors, and deinker aids.

Bulletin 592 describes the interesting Betz approach to microbiological control in pulp and paper mills. May we send you a copy? No obligation, of course.

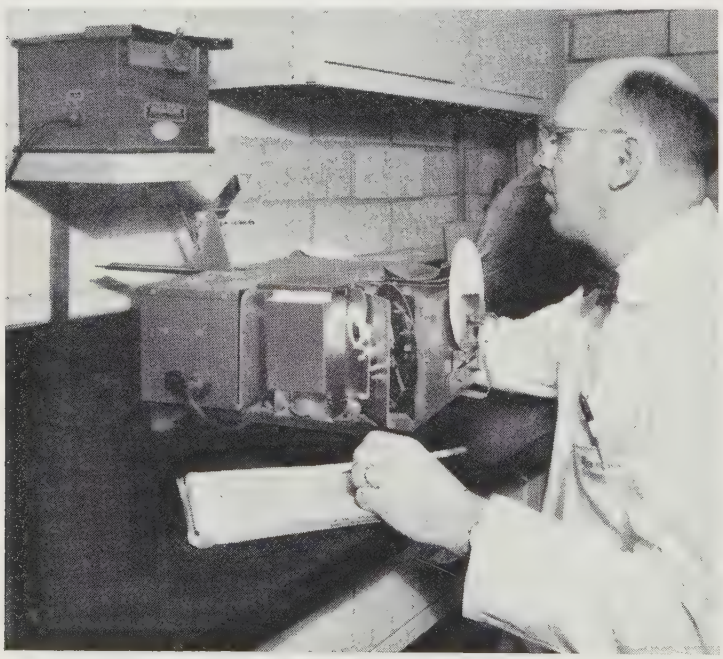
BETZ LABORATORIES, INC., Gillingham & Worth Streets, Philadelphia 24, Pa.
In Canada: BETZ LABORATORIES, LIMITED, Montreal 1.

BETZ

CONSULTANTS ON MICROBIOLOGICAL CONTROL

# U.S.I. SERVICES THE PAPER INDUSTRY WITH TECHNICAL LAB ASSISTANCE...

**IN PACKAGING**—From studies such as this test of heat seal strength, U.S.I.'s Polymer Service Laboratories develop recommended procedures for all aspects of polyethylene packaging.



**IN PULPING**—Tech Service Engineer at U.S.I.'s laboratory-scale pulp and paper "plant" determines brightness of a hand sheet he has made from customer's pulp, on Hunter Multipurpose Reflectometer. He will also test it for tensile and bursting strengths, folding resistance.

## in pulping
## in converting
## in packaging

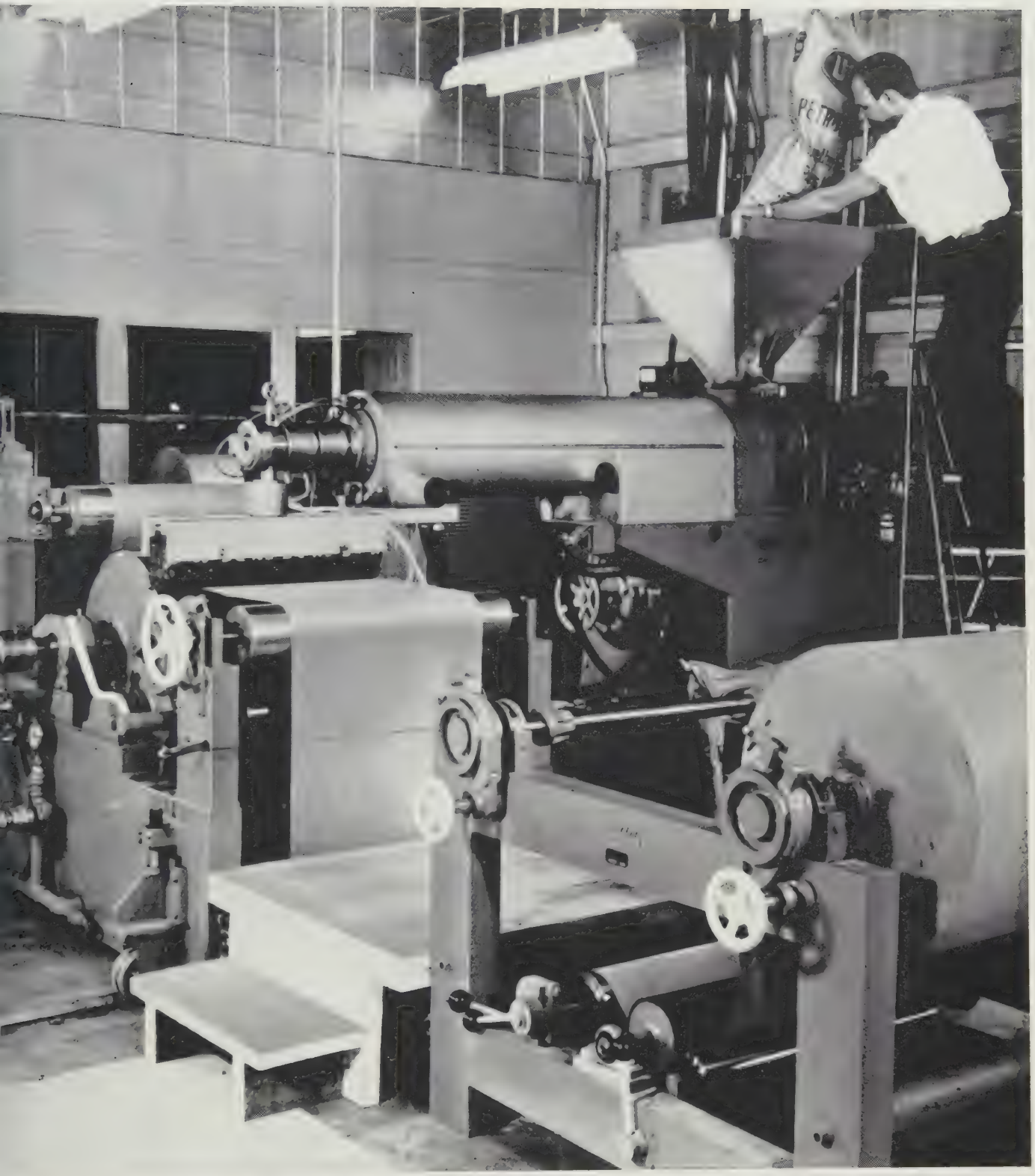
Whether you're pulping, converting or packaging paper products, U.S.I. has a laboratory and staff devoted to technical service in your field. Its job: to see that U.S.I. products for the paper industry give you the results you need in your operation.

U.S.I.'s pulp and paper laboratory—built eight years ago when U.S.I.'s Huntsville, Alabama, chlorine and caustic soda plant began operation—is a miniature paper plant, complete with auxiliary testing equipment. Here our engineers work on bleaching and assist with other applications of U.S.I.'s chlorine, caustic, ammonia, sodium peroxide . . . determine systems, techniques, types and concentrations of chemicals so that customers will know how to produce the brightest pulp with minimum fiber degradation.

Another lab at Tuscola, Illinois, is staffed with experts on polyethylene technology—including coating of paper and board, and packaging of paper products for the consumer market. They have equipment to duplicate commercial production and testing techniques . . . to tackle any problem involving an application for PETROTHENE® polyethylene resins.

A vital part of the Polymer Service Laboratories' work is development of new polyethylene paper coating and paper products packaging techniques along with design of necessary equipment.

Write or call for more information on how these services can work for you in improving your products . . . expanding your markets.



**IN CONVERTING** – Duplicating commercial equipment in everything but width, this coating machine at U.S.I.'s Polymer Service Laboratories is a key factor in developing new polyethylene resins for specific substrates. Latest products to come out of such work are three new PETROTHENE® resins designed for paper coating applications.


**U.S.I INDUSTRIAL CHEMICALS CO.**
Division of National Distillers and Chemical Corp.
99 Park Ave., New York 16, N. Y.
*Branches in principal cities*

CHLORINE • CAUSTIC SODA • SODIUM PEROXIDE • AMMONIA • PETROTHENE® POLYETHYLENE

# *For good boxboard mix good materials with good refining*

Bauer Pump-Through Refiners help Federal Paper Board Company, Inc. meet its customers' demands for better packaging materials. Use of these refiners on virgin pulp and secondary fibers for liner stock preserves fiber length and produces a stronger, freer draining, better forming furnish. The result: a good boxboard with high sales appeal. For firsthand information on how Pump-Through Refiners can help in your mill, call your Bauer representative.

THE BAUER BROS. CO.

SPRINGFIELD, OHIO

*One of the two Bauer 32-inch Pump-Through Refiners working on top liner stock at Federal's Mill at New Haven, Connecticut.*

WHITER AND BRIGHTER WITH UNITANE®

**OR-540**
Titanium Dioxide

## FOR QUICK DISPERSION

The uniformly fine particles of OR-540 wet quickly and disperse easily, evenly... give your paper coatings the utmost in opacity, whiteness and finish. Ask your Cyanamid Pigments representative for complete information.

CYANAMID

AMERICAN CYANAMID COMPANY. Pigments Division
30 Rockefeller Plaza, New York 20. N.Y.
Branch Offices and Warehouses in Principal Cities

*B.C. Forest Service*

## PROMISE HIGH QUALITY BLEACHED PAPER PULP IN 1961

Early in 1961, a new high quality market pulp mill will go on stream near Castlegar, British Columbia, at the foot of the Arrow Lakes region of the Columbia River. Celgar Limited will utilize almost 900,000 acres of prime northern-type forest lands held under a Tree Farm Licence in perpetuity.

All the resources necessary for efficient mill operation are available — wood to meet any future demand, plentiful water from the clear Columbia, power and gas, transportation from the mill site to markets, and trained people from established industrial communities in the area.

Celgar Kraft will combine many of the best qualities of Northern and Western pulps to produce a product with an exceptional balance of properties. The long, tough fibres from high-density softwoods develop high bursting strengths coupled with outstanding tear resistance over a wide range of freeness, and in a variety of stock preparation equipment.

**COLUMBIA PULP SALES LIMITED** has been formed to distribute Celgar Kraft pulps and Columbia Cellulose sulphite pulps. Offices are located at:
1030 West Georgia St., Vancouver 5, B.C.
1600 Dorchester St. West, Montreal 25, P.Q.

V4247-1

Celgar Kraft

# Removes Filterable Solids from Paper Machine Water

at Eastman Kodak Company

**EIMCO Disc SAVEALL**

To control waste water from its paper mill, Eastman Kodak Company required a filter capable of recovering fiber from paper machine water. The unit, now located in the company's Kodak Park Works plant in Rochester, New York, had to be highly sensitive to changes in feed, specially designed for high recirculation, and built to handle a slurry containing various chemicals.

For this application, Eimco engineered the 9-ft. 2-in. diameter by five disc filter shown above. The filter has a special high capacity valve, with bridging designed for 70 per cent recirculation. Disc speed is controlled by a level sensing device in the tank. When slurry level rises, disc rotation is speeded. When level falls, rotation is slowed. Parts exposed to paper machine effluent are stainless steel.

In pulp and paper, Eimco has engineered many economical equipment installations for filtration . . . wastes removal . . . pulp washing . . . water treatment . . . recausticization. The Eimco representative in your area is a skilled specialist in equipment for liquid-solids separation. He can show you how Eimco vacuum and pressure filters — and Eimco-Process equipment for gravity and flotation clarification — can be a profitable investment for you.

"ADVANCED ENGINEERING AND QUALITY CRAFTSMANSHIP SINCE 1884"

**THE EIMCO CORPORATION**

EXPORT OFFICE: 51 - 52 SOUTH STREET, NEW YORK, N. Y.
BRANCHES AND DEALERS IN PRINCIPAL CITIES THROUGHOUT THE WORLD

EIMCO

**FILTER DIVISION**
634 SOUTH 4TH WEST
SALT LAKE CITY, UTAH — U.S.A.

RESEARCH AND DEVELOPMENT CENTER
301 SO. HICKS ROAD, PALATINE, ILLINOIS

B - 592

DOW | LATEX

*12-pt. Garamond type* impression printed originally on paper coated with Dow Latex 630 and magnified approximately 85 times to show paper surface uniformity. The uniform impression and ink distribution greatly improve print quality.

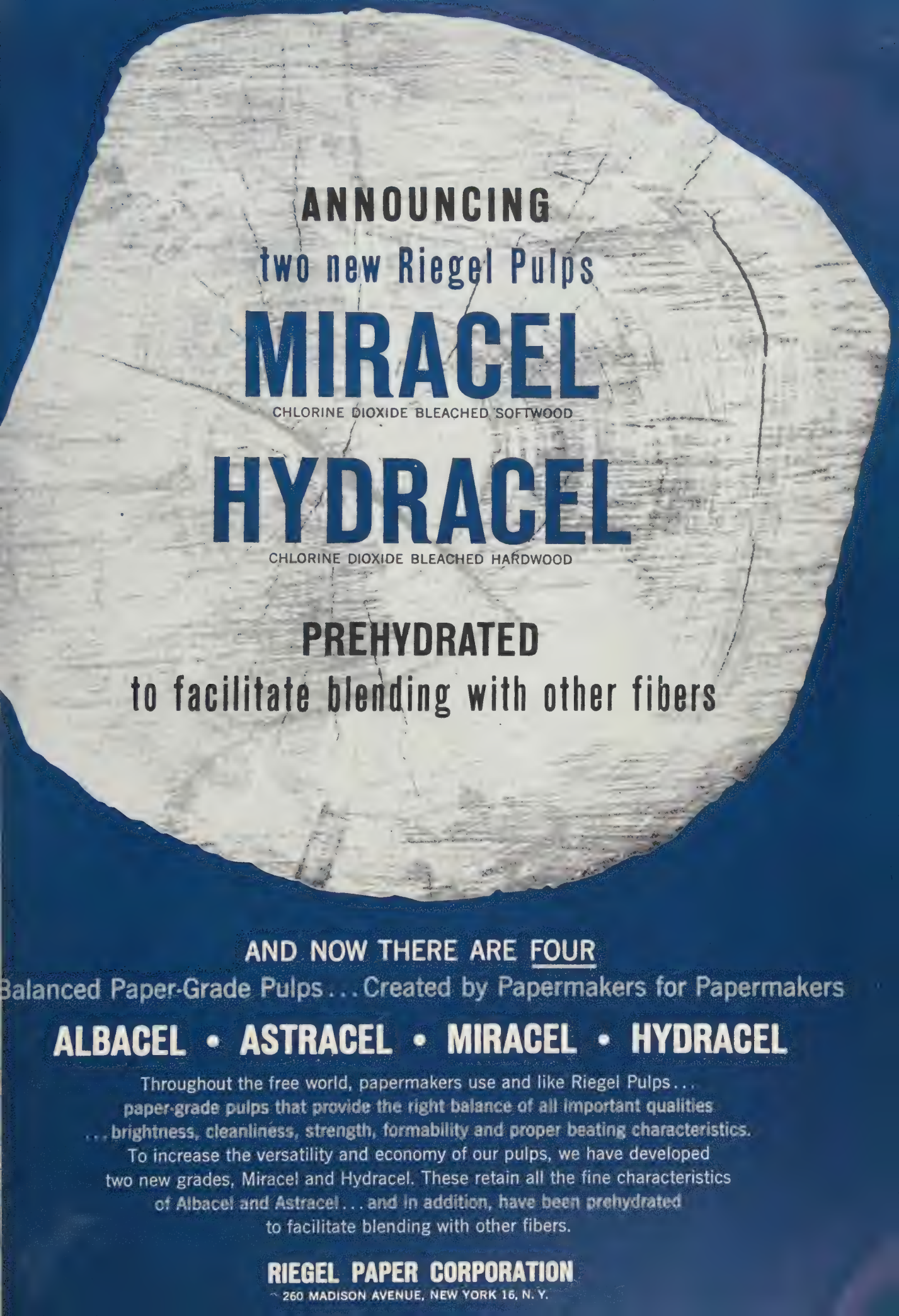
## Now . . . better control of paper uniformity with **NEW DOW LATEX 630**

- **Excellent Mechanical Stability!**
- **Superior Pick Resistance!**
- **Excellent Starch Compatibility!**

Three good reasons why new DOW LATEX 630 can help you make . . . help you sell . . . better paper than ever! You'll find it far easier to produce uniform paper with smoother, more pick resistant coatings made from Dow Latex 630. Paper surfaces provide a new high in printability, reproducing both illustrations and type with remarkable sharpness and realism. Dow Latex 630 will give you the coating quality you usually associate with higher cost!

*Contact Dow now* for detailed information to help you make the most of new DOW LATEX 630! Write to THE DOW CHEMICAL COMPANY, Midland, Michigan, Coatings Sales Department 1934FC6.

**THE DOW CHEMICAL COMPANY • MIDLAND, MICHIGAN**




AND NOW THERE ARE FOUR

Balanced Paper-Grade Pulps . . . Created by Papermakers for Papermakers

**ALBACEL • ASTRACEL • MIRACEL • HYDRACEL**

Throughout the free world, papermakers use and like Riegel Pulps . . . paper-grade pulps that provide the right balance of all important qualities . . . brightness, cleanliness, strength, formability and proper beating characteristics. To increase the versatility and economy of our pulps, we have developed two new grades, Miracel and Hydracel. These retain all the fine characteristics of Albacel and Astracel . . . and in addition, have been prehydrated to facilitate blending with other fibers.

**RIEGEL PAPER CORPORATION**

260 MADISON AVENUE, NEW YORK 16, N. Y.

# The KADY® MILL

## COATING COLOR

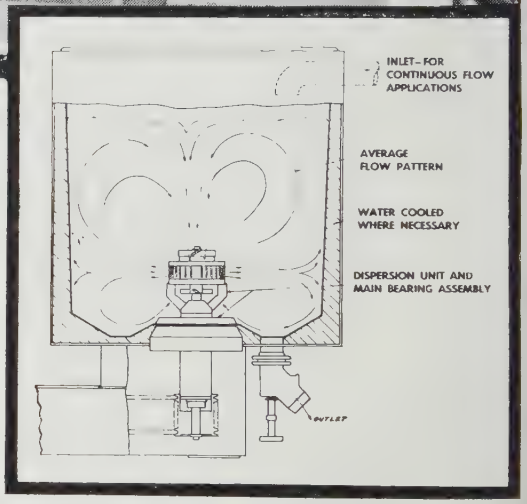
in

## MINUTES

instead of

## HOURS

*




- ★ **Cook Protein, Casein or Starch in presence of pigment efficiently and economically.**
- ★ **Color for Machine or Off Machine coating in one operation.**
- ★ **Low Viscosity with high solids.**
- ★ **Reduce Binder percentage.**
- ★ **Develops optimum opacity and gloss.**

Over 50 paper plants have approved the advantages and economy of coating color production by the KADY method. The uniformity of viscosity, optimum value from Ti $0_2$, calcium carbonate, satin white and from whichever adhesive or combination of adhesives used, prove the superiority of the KADY method to any other.

If you want continuous processing or have a color system deaerating problem to overcome, let us give you the complete story of KADY applications to suit your specific requirements. Many quality control problems on all types of coaters are being solved effectively, color application improved and superior finish obtained by a simple, low cost installation of a KADY MILL!

* *Pictured above is the 200 gallon model 4BH-60. Other models, including the new T series, in capacities from ½ to 750 gallons.*

*Convenient Lease or Time Payment Plan*

**KADY® proven best in WORLD WIDE installations:**

- United States
- Canada
- England
- Norway
- Sweden
- Finland
- Denmark
- Germany
- France
- Belgium
- Japan
- Mexico

Please address inquiries for Continental Europe to:

**KADY INTERNATIONAL (EUROPA) N.V.**
**RAAMGRACHT 4**
**AMSTERDAM - HOLLAND**

# Kinetic Dispersion corp.

Buffalo, N. Y. 95 Botsford Place

Illustration courtesy American Stores Co.

## Appetizing letterpress...on RHOPLEX®-coated stock

Smell the sticky buns? The scented ink merely heightens the illusion created by the combination of superb letterpress printing and the flawless printing surface made possible by the RHOPLEX 100% Acrylic emulsion binder in the paper coating. RHOPLEX is thermoplastic, flows and levels uniformly and buffs to a very high gloss under the heat and pressure of the calender rolls. Low viscosity of RHOPLEX emulsions permits high solids formulations which are easy to handle and to apply uniformly. RHOPLEX emulsions are ideal binders for coatings on both printing papers and paper board.

Write for the 16-page booklet, "RHOPLEX Acrylic Emulsions in Paper Coatings", for full formulating information.

*Chemicals for Industry*

**ROHM & HAAS COMPANY**

THE RESINOUS PRODUCTS DIVISION

Washington Square, Philadelphia 5, Pa.

# RHOPLEX

# New Idea in Material Handling Cuts Costs at Bird & Son, Inc.

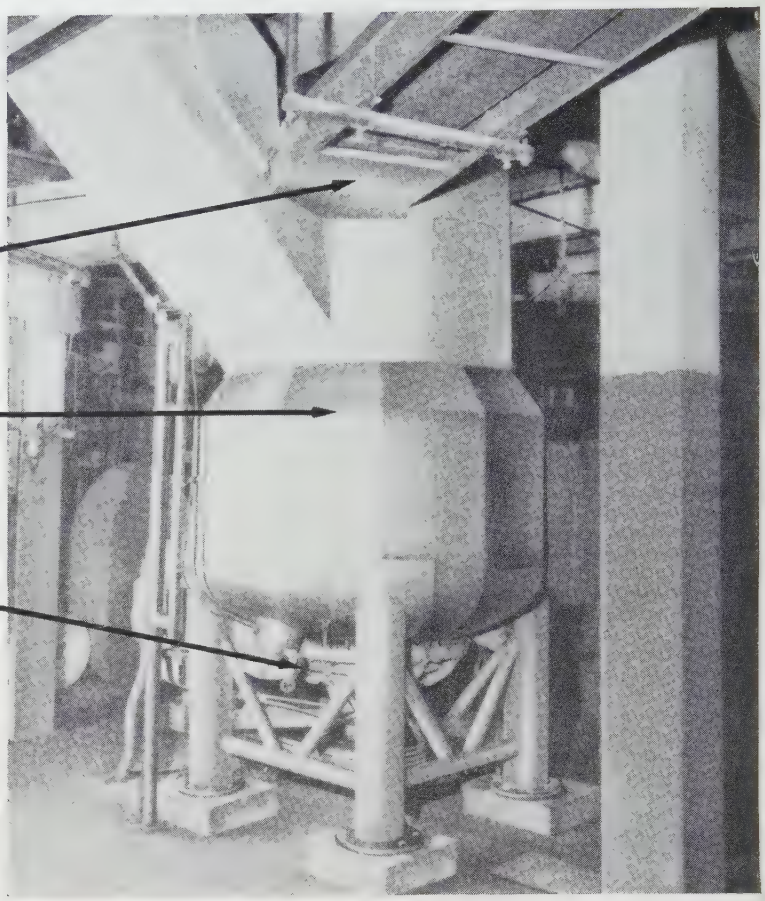
From
Converting Mill . . .

Via Conveyors

To Pulper

To Pump*

To Pulp Mill



## With the Impco Solvo® Pulper

The Model 2U Solvo Pulper, playing a dual roll at Bird & Son, Inc., East Walpole, Massachusetts, has sharply reduced previous material handling costs. It is operating continuously under automatic control as both a material handler and a pulper. Boxboard broke from the converting machines is delivered by conveyors to the Solvo which simultaneously pulps and pumps it to the pulp mill. The units' single 50 HP motor handles both pulping and pump-away demand at a 24 ton/day rate.

This is one of a wide variety of Solvo Pulper applications. Others include de-ink cooking, dry end broke handling, paper machine furnish pulping, transfer of high yield cooked chips to refiners as well as the normal pulping of broke, wet strength and waste paper. Units are available for any capacity requirement.

*The pulping element, extractor plate and stock pump are one rotating assembly.

IMPCO®

**IMPROVED MACHINERY INC.**
**NASHUA, NEW HAMPSHIRE**
**In Canada: Sherbrooke, Machineries Limited, Sherbrooke, Quebec**

Oldest integrated paper mill in the country:
Tileston & Hollingsworth Co., Hyde Park, Mass.

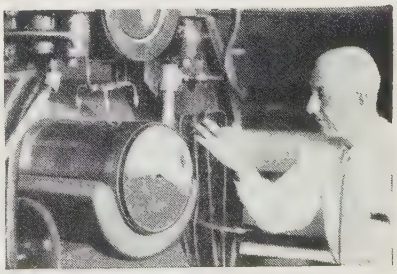
# Lubrication engineer switches 230-year-old mill to Cities Service Lubricants

William D'Entremont, Lubrication Engineer for the Boston Office of Cities Service, spent three days at the Tileston & Hollingsworth paper mill making an extensive survey of their operations. He checked over dozens of machines with hundreds of lubrication points. His report convinced management to switch to Cities Service lubricants. Mr. D'Entremont's recommendations reduced the number of lubricants used by the company by one third, and at the same time increased efficiency of operations.

Typical of the Cities Service lubricants now used by Tileston & Hollingsworth are several types of Trojan grease, each fulfilling a specific and rigorous requirement. The unique properties of Trojan greases are the result of scientific use of laboratory-tested fortifying chemicals. Mineral oils comprise the largest percentage of the ingredients in Trojan greases. Only such oils are employed that are known to give the best results required of a given type—a knowledge gleaned from years of research and experience in the manufacture of high grade greases for a host of critical customers.

To learn how Cities Service lubricants can help you in your business, call the Cities Service Lubrication Engineer in your area. Or write: Cities Service Oil Company, Sixty Wall Tower, New York 5, N. Y.

The original charter establishing this company was issued in 1728 by the Provincial Government in Mass. In its first year the charter called for the company to make *"Two hundred Rheams of good Merchantable Brown Paper and Printing Paper"* plus *"Fifty Rheams of Writing Paper of equal goodness with the Paper commonly stampt with the London Armes."* Today the mill produces that much paper in an hour.



William D'Entremont checks paper mill's machinery. His recommendations reduced number of lubricants used by company by one third.

CITIES SERVICE
QUALITY PETROLEUM PRODUCTS

# "Our new truck service provides one-day delivery of liquid $SO_2$ – in bulk or ton drums – within a radius of nearly 1000 miles"

Dr. Daniel W. Duncan, vice president in charge of manufacturing at Virginia Smelting Company

Dan Duncan, a vice president of Virginia Smelting Company, discusses the excellent service "Virginia" offers customers who use liquid sulfur dioxide.

**Q Does "Virginia" offer unusually prompt delivery of $SO_2$?**

**A** Yes, within hours by means of our truck service. Railroad cars, either tanks or multiunit ton drum cars, can take a week or more for delivery.

**Q In addition to rapid delivery, what other attractive features does your truck service have?**

**A** Our trucks are designed for safety and convenience of unloading. Our drivers handle the unloading of both bulk tanks and ton drums. The special unloader carried on the trailer can quickly unload the ton drums on the customer's platform or lift truck, eliminating the need for a crane or derrick at the customer's plant.

**Q What are the advantages of your tank trucks?**

**A** Each tank truck hauls 15 to 18 tons of bulk $SO_2$. By use of our modern equipment, with sleeper cabs and two drivers, we can take care of a customer's needs on short notice. There is no necessity for interrupting operations and waiting for a railroad tank car.

**Q Suppose a customer has an emergency situation in the middle of the night?**

**A** It isn't unusual for us to get orders like this. We consider it an important service to our customers. We have qualified crews on duty 24 hours a day. These men can load and dispatch a truck on very short notice. And I might point out that with our production and storage capacity our customers never have to worry about their $SO_2$ supply. We can always fill their orders.

"Virginia" liquid sulfur dioxide, of consistently high purity, is available for immediate delivery whenever and wherever needed. Phone, wire or write for prices and any other information desired.

**Industrial Division**
**VIRGINIA SMELTING COMPANY**
Dept. 386, West Norfolk, Va.

VIRGINIA® Chemicals

Field Offices: New York • Boston • Chicago • Atlanta
Asheville • Philadelphia • Akron • Seattle • Memphis

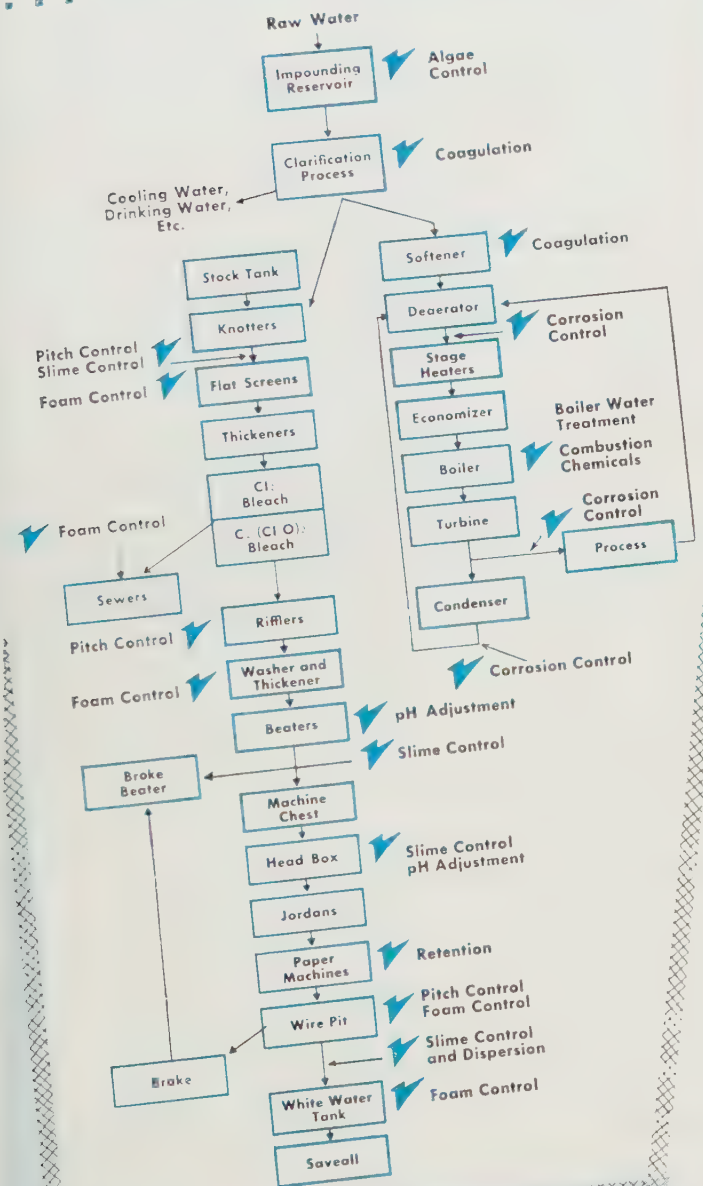
*Available in Canada and many other countries*

HERE IS THE

# COMPLETE *Nalco* PROGRAM

for Better Products at Lower Cost

## . . . IN A TYPICAL MILL




NALCO has the *widest variety* of formulas to assure results in your mill, too. Here are some examples . . . representative Nalco products listed under headings which indicate the job they do. And the chart at left tells you where they are used. Your Nalco Representative will tell you more about them — or write direct to Nalco.

**ALGAE CONTROL**
Nalco Cuprose · Nalco 21-S · Nalco 201 · Nalco 234 · Nalco 236 · Nalco 237

**COAGULATION**
Nalco 600 · Nalco 650 · Nalco 680

**COMBUSTION CHEMICALS**
Nalco 155 · Nalco 156 · Nalco 156-C

**FOAM CONTROL**
Nalco 71 · Nalco 71-B · Nalco 71-C · Nalco 71-D5 · Nalco 71-K · Nalco 72

**CORROSION CONTROL**
Nalco 19 · Nalco 35 · Nalco 353 · Nalco 918

**pH ADJUSTMENT**
Nalco 680

**PITCH CONTROL**
Nalco 818

**RETENTION AND CLARIFICATION**
Nalco 600 · Nalco 650 · Nalco 680

**SLIME CONTROL AND DISPERSION**
Nalco 21-S · Nalco 21-M · Nalco 201 · Nalco 234 · Nalco 236 · Nalco 237

**BOILER WATER TREATMENT**
Nalco 75 · Nalco 718 · Nalco 728 · Nalco 752

*National Aluminate Corporation is now*

**NALCO CHEMICAL COMPANY**

6197 West 66th Place • Chicago 38, Illinois

*Subsidiaries in England, Italy, Mexico, Spain, Venezuela and West Germany*

*In Canada—Alchem Limited, Burlington, Ontario*

THE *Nalco*®

**SYSTEM . . . Serving the Paper Industry through Practical Applied Science**

# By every standard... WEST END MEASURES UP AS THE QUALIFIED SUPPLIER OF SALT CAKE

- ACCURATE PROCESSING OF ORDERS
- UNIFORMLY HIGH QUALITY
- ABUNDANT STORAGE
- FLEXIBLE AND EFFICIENT LOADING AND SHIPPING
- EXTENSIVE PRODUCTION CAPACITY
- VAST NATURAL SOURCE OF RAW MATERIAL
- ALL COMMITMENTS SCRUPULOUSLY MET
- FRIENDLY, HELPFUL ATTENTION TO INDIVIDUAL NEEDS
- PROMPT, AUTHORITATIVE ANSWER TO EVERY INQUIRY

However you view your needs, you will find in West End a unique coordination of specialized services, extensive production facilities and product excellence essential to the prompt, efficient handling of individual requirements.

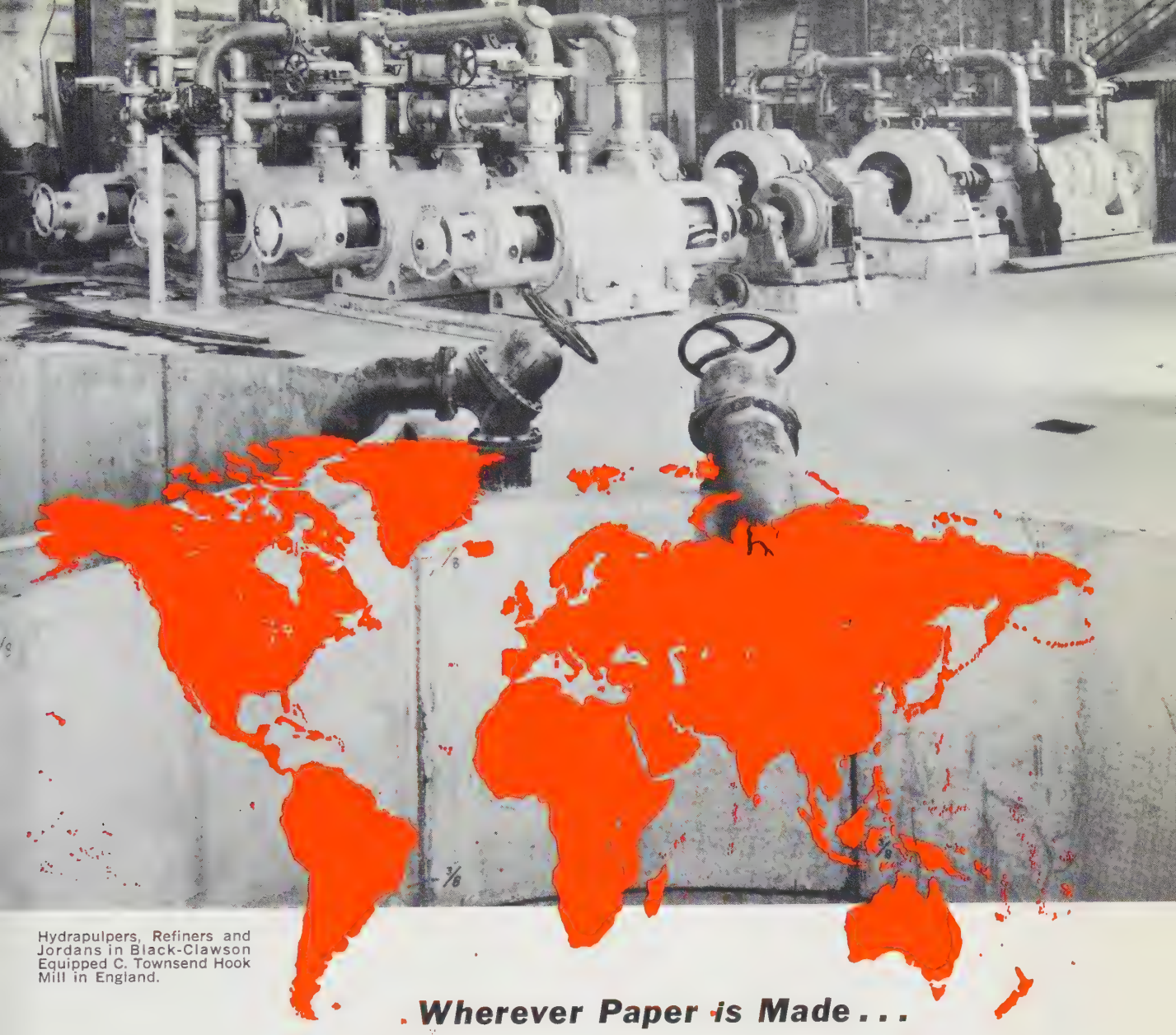
## *Abundant storage*

Vast reserves of finished products stored in extensive tank facilities are immediately available to meet any regular or emergency requirement promptly and easily regardless of market conditions. As West End increases production to serve an ever-expanding market for its products, storage facilities are constantly being enlarged to maintain the abundant level of chemicals in reserve.

Stauffer CHEMICALS SINCE 1885 — 75 YEARS OF SERVICE TO INDUSTRY AND AGRICULTURE

WEST END CHEMICAL COMPANY • DIVISION OF STAUFFER CHEMICAL COMPANY

636 CALIFORNIA, SAN FRANCISCO 8, CALIF. • PLANT: WESTEND, CALIF.



Hydrapulpers, Refiners and Jordans in Black-Clawson Equipped C. Townsend Hook Mill in England.

## *Wherever Paper is Made . . .* Black-Clawson is There

Black-Clawson offers technical and manufacturing facilities geared to serve the expanding pulp and paper industry on a world-wide basis.

For example, the entire line of Black-Clawson American pulp and paper making machinery is manufactured for the British-European paper centers by Black-Clawson International, Ltd., at its Newport, England plant.

Typical of their service is this stock preparation system . . . Hydrapulpers, Jordans, Hydrafiners, Selectifier Screens, etc. which precedes the new and modern Black-Clawson newsprint machine in operation at C. Townsend Hook & Co., Ltd. in Snodland, Kent, England.

PANDIA DIVISION PULP MILL EQUIPMENT

SHARTLE DIVISION STOCK PREPARATION EQUIPMENT

B

PAPER MACHINE DIVISION PAPER & BOARD MACHINES

DILTS DIVISION CONVERTING MACHINERY

# THE BLACK-CLAWSON COMPANY

**Executive Offices: 250 Park Ave., New York, N. Y.**

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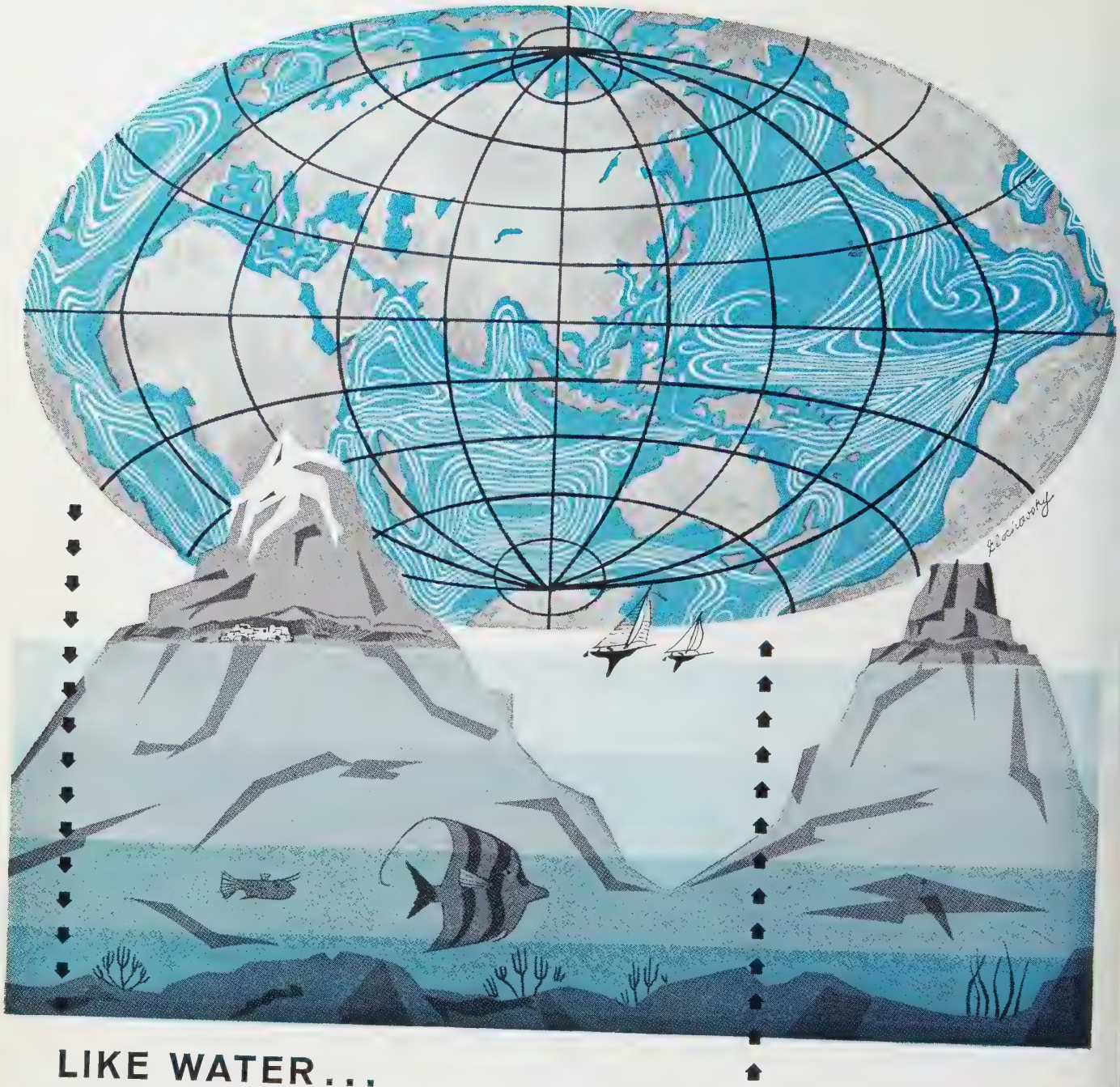
BLACK-CLAWSON INTERNATIONAL, LTD., 18/19 SAVILLE ROW, LONDON, ENGLAND

Plants: Hamilton, Ohio • Middletown, Ohio • Watertown, N. Y. • Fulton, N. Y. • Newport, England

International Representation in: New York, London, Paris, Zurich, Mexico City, Rio De Janeiro, Sao Paulo, Buenos Aires, Tokyo, Hamburg, Oslo, Amsterdam, Tammerfors, Milan, Lisbon, Melbourne

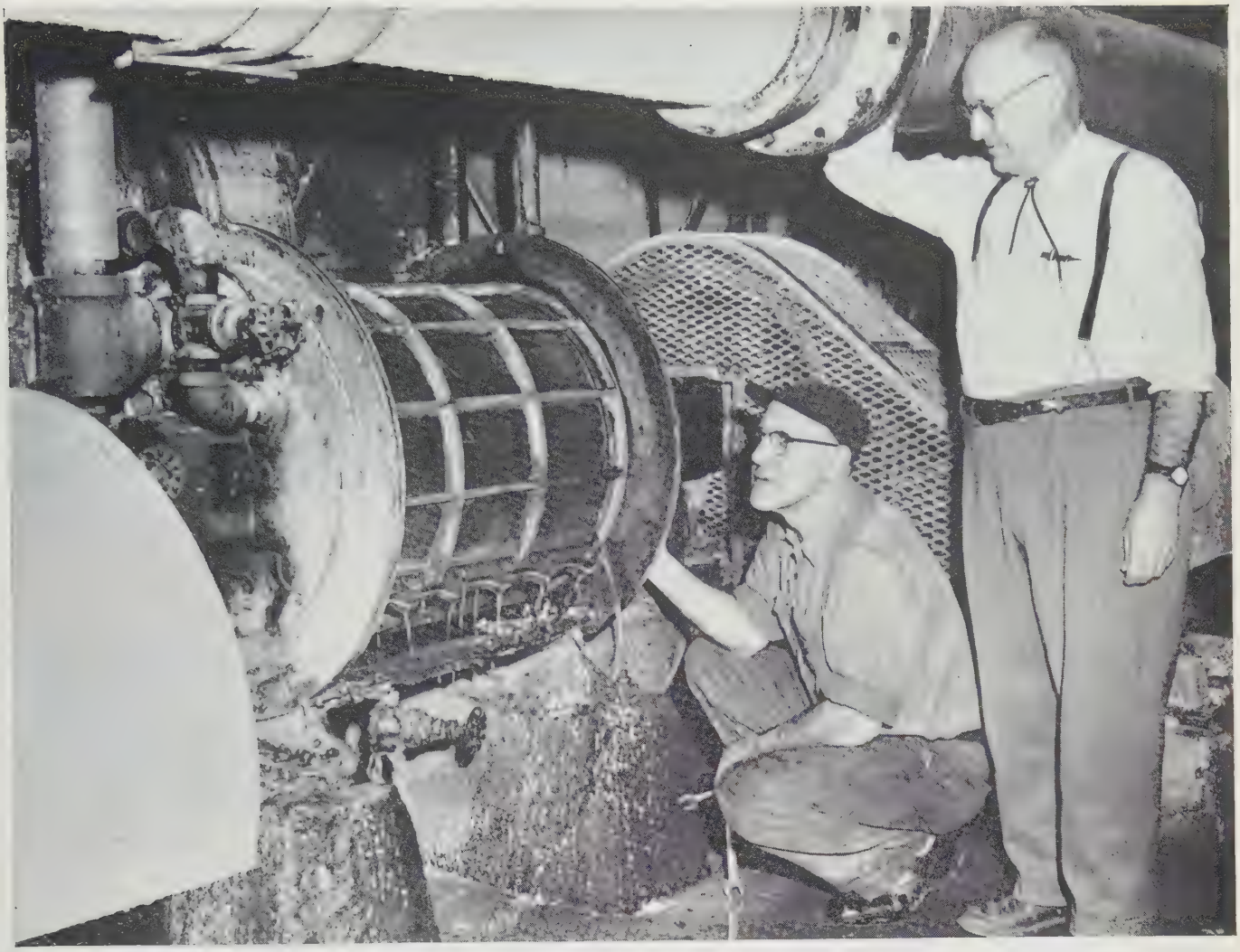


# LIKE WATER...
## coatings of Ethylex® Gums seek their own level

Perfectly smooth sheets are assured when you use Ethylex Gums in your coatings. How? The superior water-retention properties of Ethylex Gums allow time for coatings to level, minimizing surface irregularities and imperfections. The result? A smoother, more uniform surface with high pick values, excellent printability and good varnish holdout.

A. E. STALEY MFG. CO.
Decatur, Illinois

ATLANTA • BOSTON • CHICAGO • CLEVELAND • KANSAS CITY • NEW YORK • PHILADELPHIA • SAN FRANCISCO • ST. LOUIS



# St. Regis takes off the wraps to show you how they save $4000 yearly on screen plates

Until 1955, St. Regis Paper Company replaced all double plates on its fifteen rotary groundwood pulp screens four times a year. One hundred and twenty plates per year!

Since 1955, St. Regis has replaced only twelve of these plates per year, 1/10 as many. The saving? Approximately $4000 per year, by now a tidy $20,000.

### How do they do it?

Two St. Regis men took the cover off one of the rotaries. You can see the plates. They are Inconel* nickel-chromium alloy.

If you were there, you would notice two things at once. First, you would see a remarkable absence of the metal loss that enlarges the slot areas and permits fibre to slip through in "bundles." (And eventually, of course, leads to excessive breakage.) Second, your fingertips would soon disclose that edges are smooth. Nothing to start build-ups of fibre strings.

Now here is a curious coincidence. In a totally independent 52-day, in-plant corrosion test of proposed rotary screen materials processing groundwood stock, Inconel alloy corroded just exactly 1/10 as much as phosphor bronze.

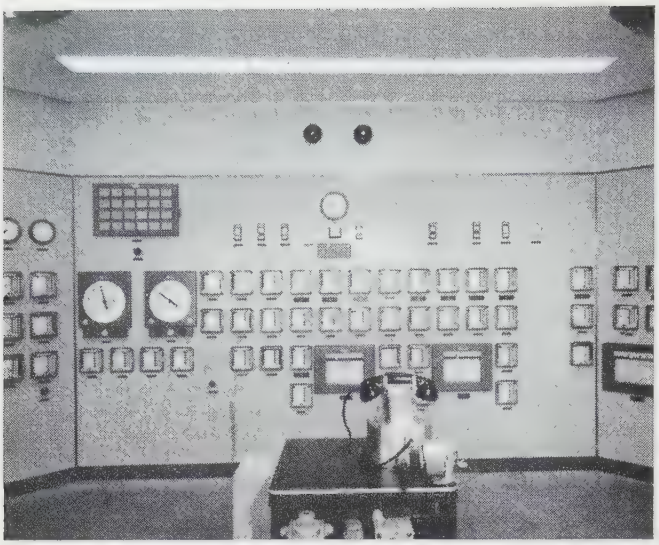
Experience shows, too, that applied stress, crevices, welding, intermittent wetting, and/or vapor phase exposure do not promote stress-corrosion cracking, intergranular corrosion or other selective attack on Inconel alloy. Not even if the medium includes chlorides and oxygen.

### Are Inconel alloy rotary screen plates readily available?

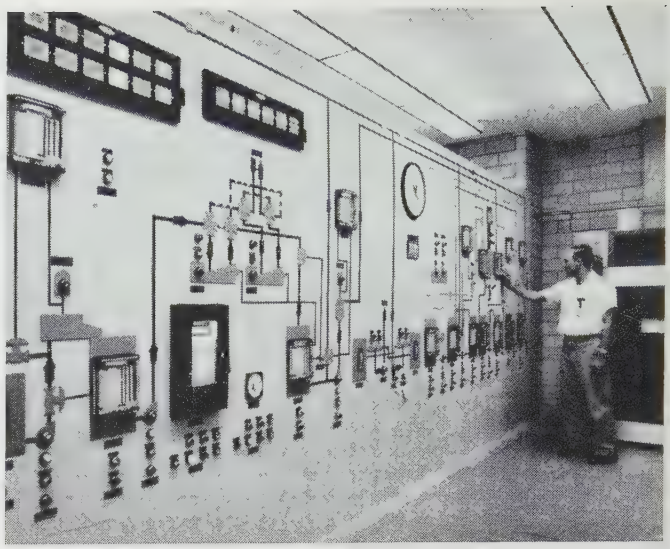
Getting Inconel alloy screen plates is no problem. The metal itself is a warehouse item. And any number of fabricators know exactly how to bring out the best in the alloy and some make Inconel alloy screen plates regularly. We'll be glad to give you names. Maybe, too, there are other ways we can help you improve metal performance. We'll gladly try. Write: *Inco trademark

**HUNTINGTON ALLOY PRODUCTS DIVISION**
**The International Nickel Company, Inc.**
**Huntington 17, West Virginia**

# INCONEL®

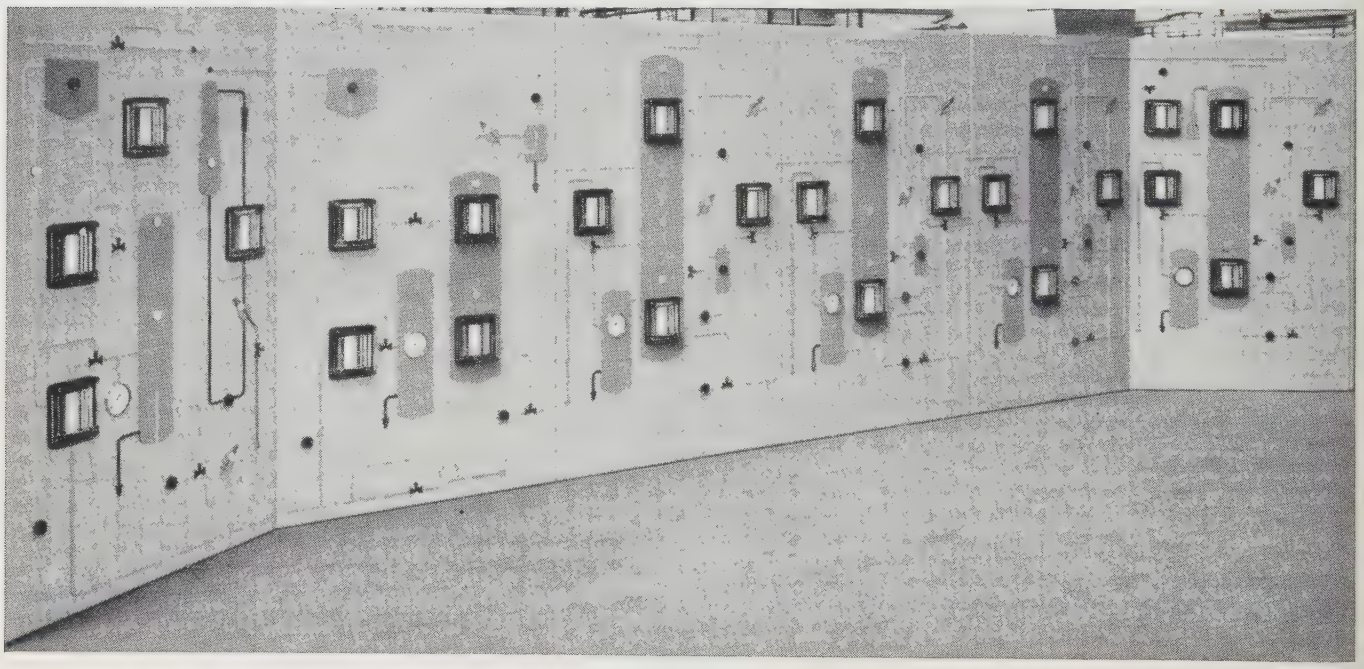


*One of several TRANSCOPE panels in a large petrochemical plant in the South West.*



*Part of an extensive TRANSCOPE installation in a famous southern paper mill.*

# "FINEST OPERATOR'S



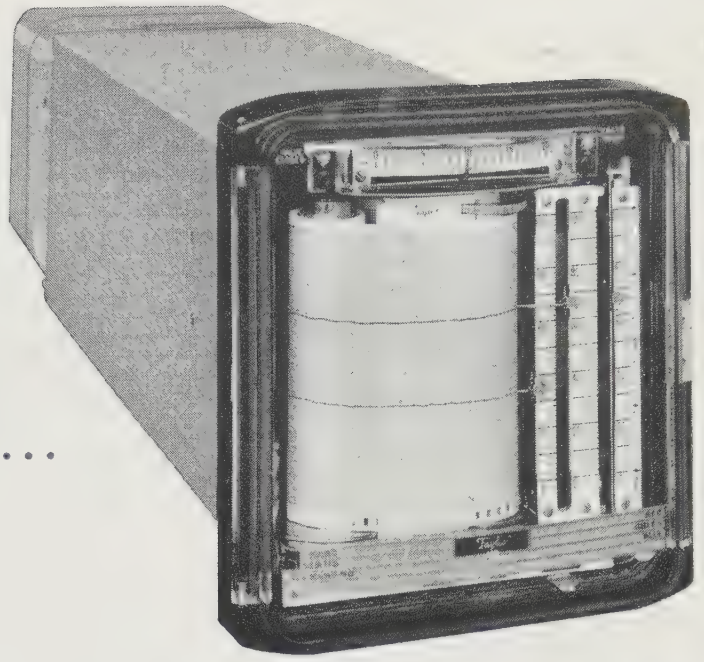
*TRANSCOPE Recorders on a graphic panel in a benzol distillation plant in England.*

Taylor Instruments

No other recorder

puts so many features

in so little panel space . . .



# TOOL YET DEVELOPED"

## *The Taylor TRANSCOPE® Recorder*

It is now generally recognized throughout industry that the Taylor TRANSCOPE (90J) Pneumatic Recorder is the finest ever built for modern miniature-instrument panels. Of equal importance, if you're in the market for such instrumentation, the 90J will not be obsoleted for many years to come. In fact user reports, after two years of field service, are so outstandingly complimentary that we believe the name TRANSCOPE will rival that of the now famous 20-year-old Taylor FULSCOPE* line for obsolescence-free dependability. Here are some of the reasons why the 90J is going to be the most imitated recorder:

**Servo-Operated Pens** with 150 times greater power, assure unprecedented accuracy of records.

**Unconfused Readability** because chart record, pen and set-point are side-by-side. Target-type pens and pointers are easiest to see, particularly at a distance. 4″ chart reads from left to right on rectilinear coordinates.

**Optional Front-of-Panel Settings** let you make control adjustments easier, quicker and better . . . from the front of panel . . . while recording!

**Stays on Automatic Control** while the plug-in recorder slide is removed for inspection, providing continuous fully automatic control.

**Complete Indicating Control Station** while recorder is removed. Optional switch lets horizontal gage at top of recorder show either process variable or output to valve.

**Receives Three Variables** to be recorded or indicated; unique, plug-in Set Point Transmitter allows continuous control. Available with Process Alarms with Memory Pointers; Automatic-to-Manual switching; Cascade or Process-output Switch, and many other features . . . all in one compact case.

*Reg. U.S. Pat. Off.

*See your Taylor Field Engineer, or write for* **Catalog 98286.**

*Taylor Instrument Companies, Rochester 1, New York, and Toronto, Ontario.*

## *MEAN ACCURACY FIRST*

# OVER 80 YEARS' EXPERIENCE
## in pulp and related services

Information cannot be inventoried—it is too hard to keep and too perishable. Yesterday's data may be as obsolete as last year's. Still, information on supplies, on prices, and on production is management's most valued tool. For information on pulp and pulp-type products, telephone C & O. One call checks many sources. Call "C & O".

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- A/S Toten Cellulosefabrik, *Bleached Sulphite*
- A/S Vestfos Cellulosefabrik, *Bleached Sulphite*
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*Agents for:*

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Spruce Falls Power & Paper Company Ltd., *Unbleached Sulphite*

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The Mohawk Corp. Ltd., *Groundwood*

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for waterproofing

Pale in color and chemically unique, **Piccopale,** a polymerized petroleum resin, is versatile in its many uses. **Piccopale Resin** is inert and heat stable, and its hydrocarbon structure assures the utmost in water and moisture resistance.

*The trademark of quality*

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Yes, when you think about it, bright white space is what
EDGAR PAPER CLAYS are—and shipped to you
in the most convenient form—bag, bulk or slurry—rail or truck.

Step #1 in the preparation of this "bright white space" is selective mining of prime kaolin clay . . . Step #2 is water washing and fractionation with controlled viscosity and particle size to each papermaker's specification . . . Step #3—drying and large volume storage for prompt deliveries.

*And—over 1,000 control tests per day to assure you highest quality Edgar clays.*

Help yourself to "bright white space" in your papers.
Call M&C for ample samples, complete technical service.

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S. R. CHRISTENSEN

# Beloit Eastern's "Bud" Hammill

In 23 years' association with the paper industry, B. L. ("Bud") Hammill has covered a wide range of mill problems and developed a keen sense of production needs. As Beloit Eastern's sales manager, he co-ordinates orders and plant output, keeps abreast of newest developments. Beloit Eastern representatives are constantly alert to serve you in the most effective manner possible. Their prime considerations are your specific requirements for finished product processing equipment. Call on these men—you'll be pleased with their recommendations.

**FINISHED PRODUCT PROCESSING EQUIPMENT**

Winders • Petite Winders • Slitters
Supercalenders • Roll Wrappers
Roll Lowering Tables • Roll and Shaft
Handling Equipment • Conveyors
Unwind Stands and Tru-Tension
Controls • and other equipment for
the paper and allied industries

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**OK BRAND** **KEOGEL** Pregelatinized—ready to use—beater starch.

**OK BRAND** **COLFLO** Cationic—effective—economical wet end additive.

**OK BRAND** **ENZYMES** Enzyme converting starches for sizing and coating adhesives.

**OK BRAND** **OXIDIZED** Oxidized starches—complete line for sizing and coating adhesive application.

**OK BRAND** **KETOGUM** A new line of corn starch derivatives for sizing and coating adhesive application.

**OK BRAND** **THINS** Economical—controlled viscosity thinboiling starches for special sizing applications.

## to meet your changing needs

Mistakes are costly. That's why you'll want to rely on Hubinger products and field service. For over three-quarters of a century, we've been developing, testing, and manufacturing starches and adhesives—always looking for new and better products. And, these products are serviced by trained field personnel, men who can help you solve the most complicated starch and adhesive problems. If your mill needs new starch products to meet special specifications, let our nearby Hubinger paper-starch technical service representative help you. You can depend on him—and Hubinger products—to meet your changing needs and do so economically.
Just phone or write us.

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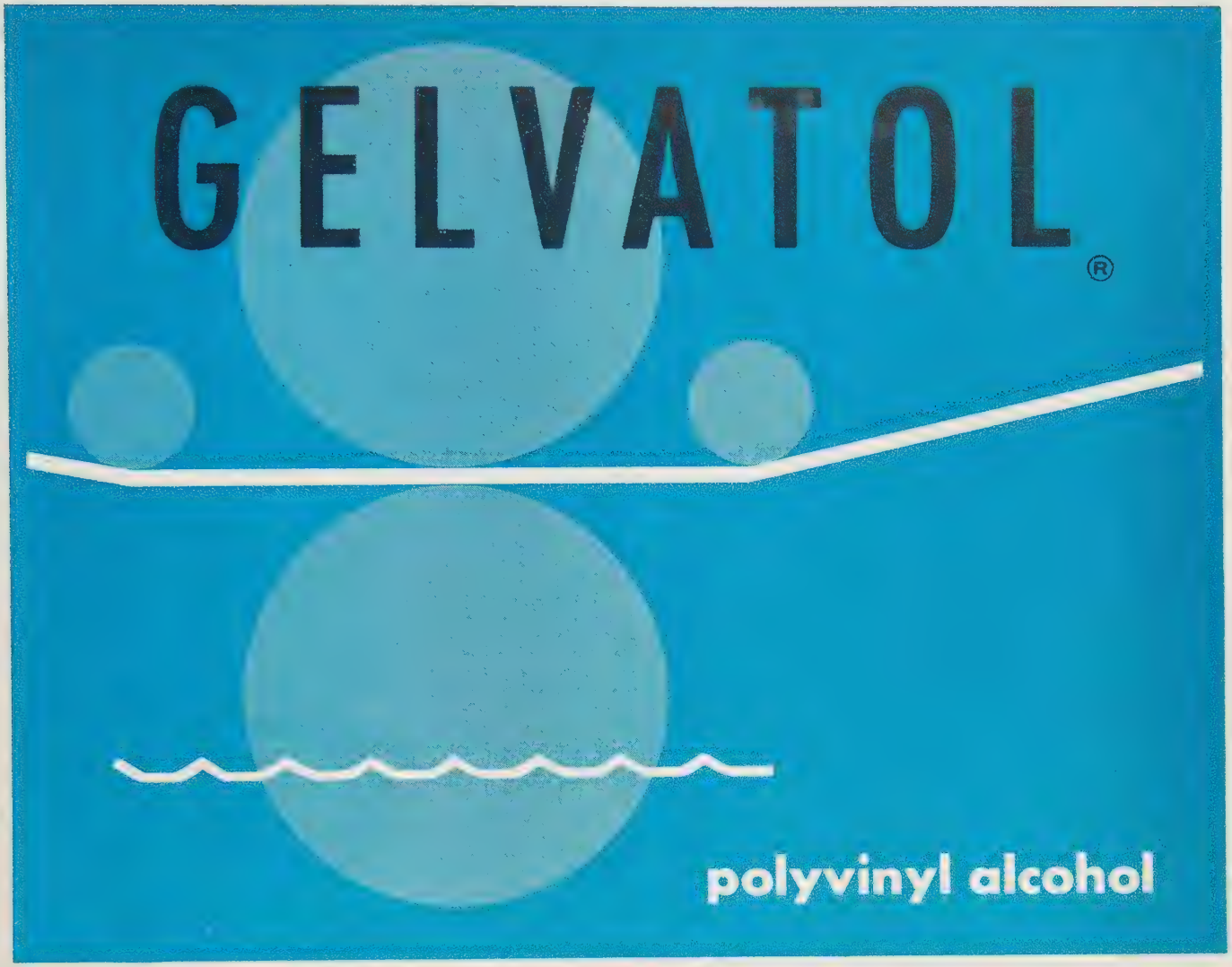
New York • Chicago • Los Angeles • Boston • Charlotte • Philadelphia




# brings out the best in pigment bindings, coatings and sizings

More and more leading paper makers are finding GELVATOL Resins highly effective for improving their products while gaining the added advantages of economy and easy handling. GELVATOL Resins' balance of properties offers you proved-in-use advantages. Apply GELVATOL from size tub, size press, water box or in coating mixes to produce:

**Improved Ink Hold-out.** Minimizes ink spread and feathering and produces prints of high gloss. Stretches ink mileage in highly absorbent stocks.

**Improved Pigment Binding.** GELVATOL Resins produce a bright, opaque sheet with excellent print qualities.

**Improved Strength.** Increases Mullen, pick resistance and fold endurance.

With capacity recently increased by 100%, GELVATOL polyvinyl alcohol is now available in an even wider variety of grades, and in any desired quantity. Write for full technical information to Shawinigan Resins Corporation, Department 8P, Springfield 1, Massachusetts.

**GELVATOL CHARACTERISTICS**

| Resin Type | Viscosity, cps. | % Residual Polyvinyl Acetate | % Hydrolysis |
|---|---|---|---|
| 1-90 | 55-65 | 0-2 | 100-99 |
| 3-90 | 45-55 | 2-4 | 99-97.9 |
| 20-90 | 35-45 | 19.5-24 | 89-86 |
| 1-60 | 28-32 | 0-2 | 100-99 |
| 3-60 | 23-28 | 2-4 | 99-97.9 |
| 20-60 | 21-25 | 19.5-24 | 89-86 |
| 1-30 | 4-6 | 0-3 | 100-98.5 |
| 20-30 | 4-6 | 19.5-21.5 | 89-87.7 |
| 40-20 | 2-3 | 37-42 | 77-72.9 |
| 40-10 | 1.3-2 | 37-42 | 77-72.9 |

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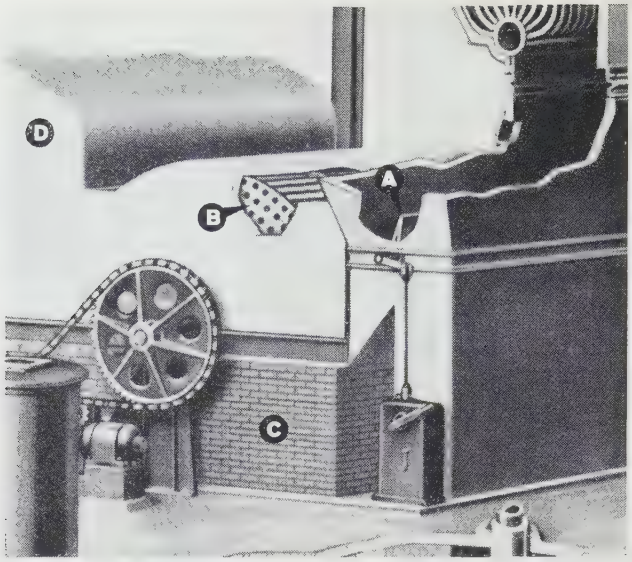
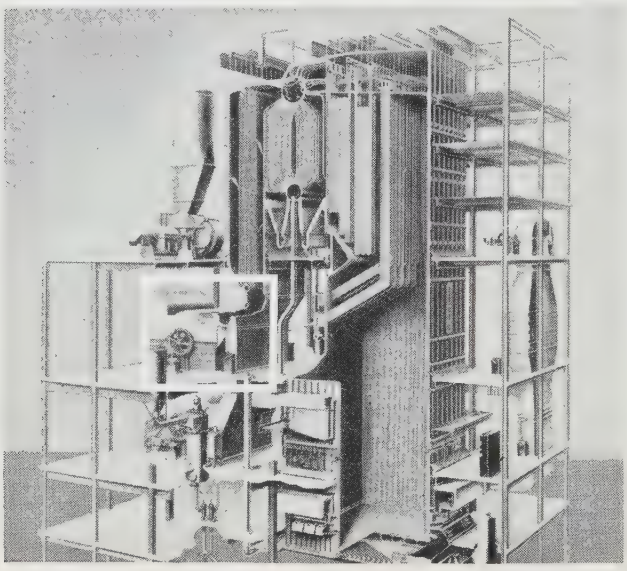
**GELVATOL® *polyvinyl alcohol by***

SHAWINIGAN RESINS®



Cutaway view of a large C-E Chemical Recovery Unit (lower left) equipped with dual Cascade Evaporators. In the evaporation process (upper left), flue gases, after passing through economizer, are divided by damper **(A)** between upper and lower Cascades. Cylindrical tube bundle **(B)** with sealed tube ends rotates slowly in a bath of hot liquor **(C)**. Hot gases passing over the wetted tubes pick up moisture and leave the Cascade at duct **(D)**. The amount of economizer surface contacting the flue gases is varied automatically — adjusting temperature and evaporation rate.

# Why CASCADE Evaporators?

***When coupled with an electrostatic precipitator,*** the C-E Cascade Evaporator affords the utmost in dependable, low-cost chemical collection and liquor concentration. For example . . .

Automatic controls provide exceptional flexibility of operation. With these controls, furnace stability is easily maintained at a high level, even though the density of liquor entering the evaporator may vary widely. And — because the Cascade Evaporator is mechanically simple and efficient — it performs with a minimum of power consumption and personal attention.

Why settle for less when you specify evaporators? The C-E *Cascade* Evaporator is your most *practical* liquor-concentrating method in the long run. The unit is standard in C-E chemical recovery installations and is recommended for new and existing systems of all makes. Write or call the Paper Mill Division in New York for particulars.

**COMBUSTION ENGINEERING**

C-E

C-267

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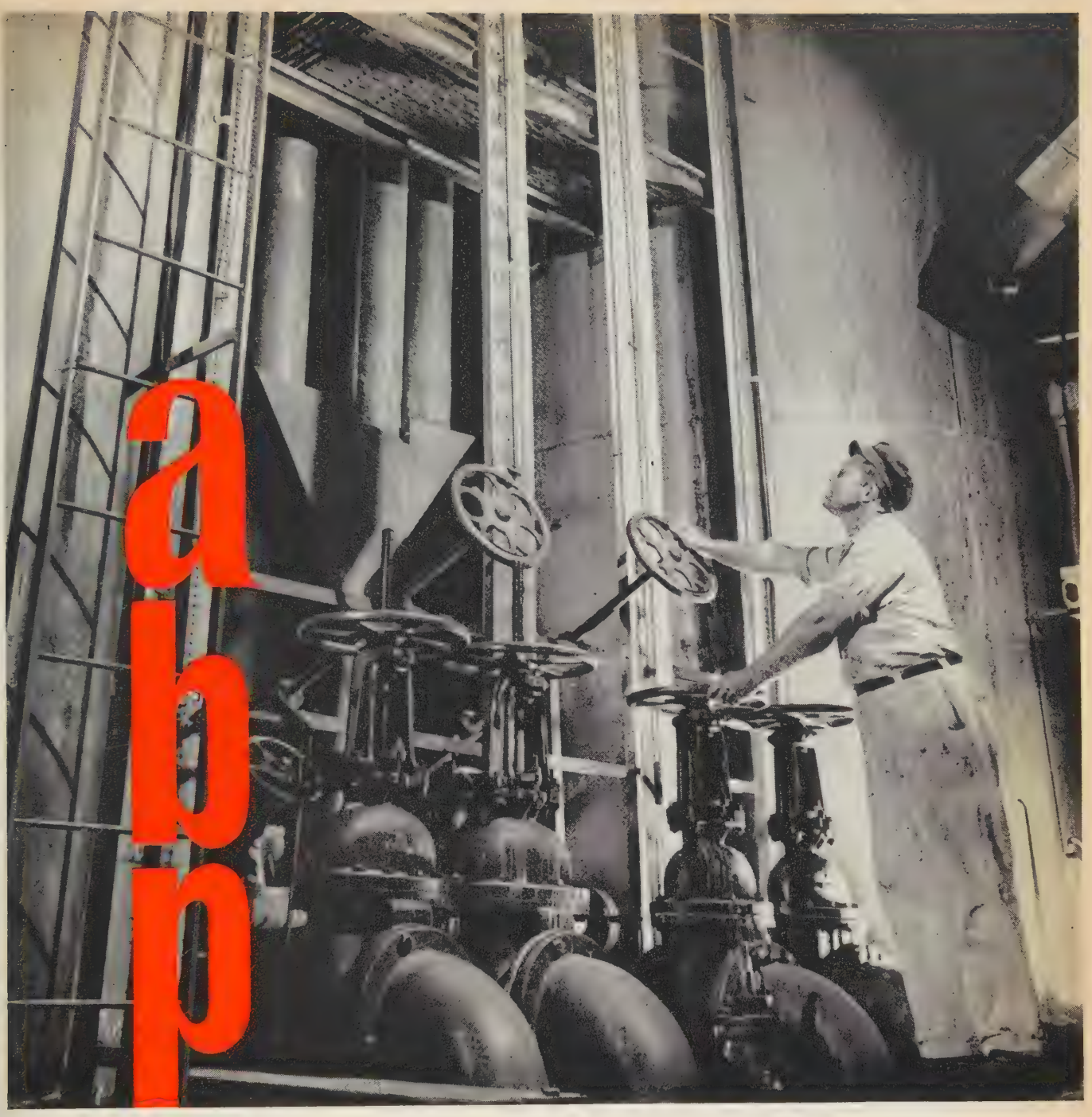


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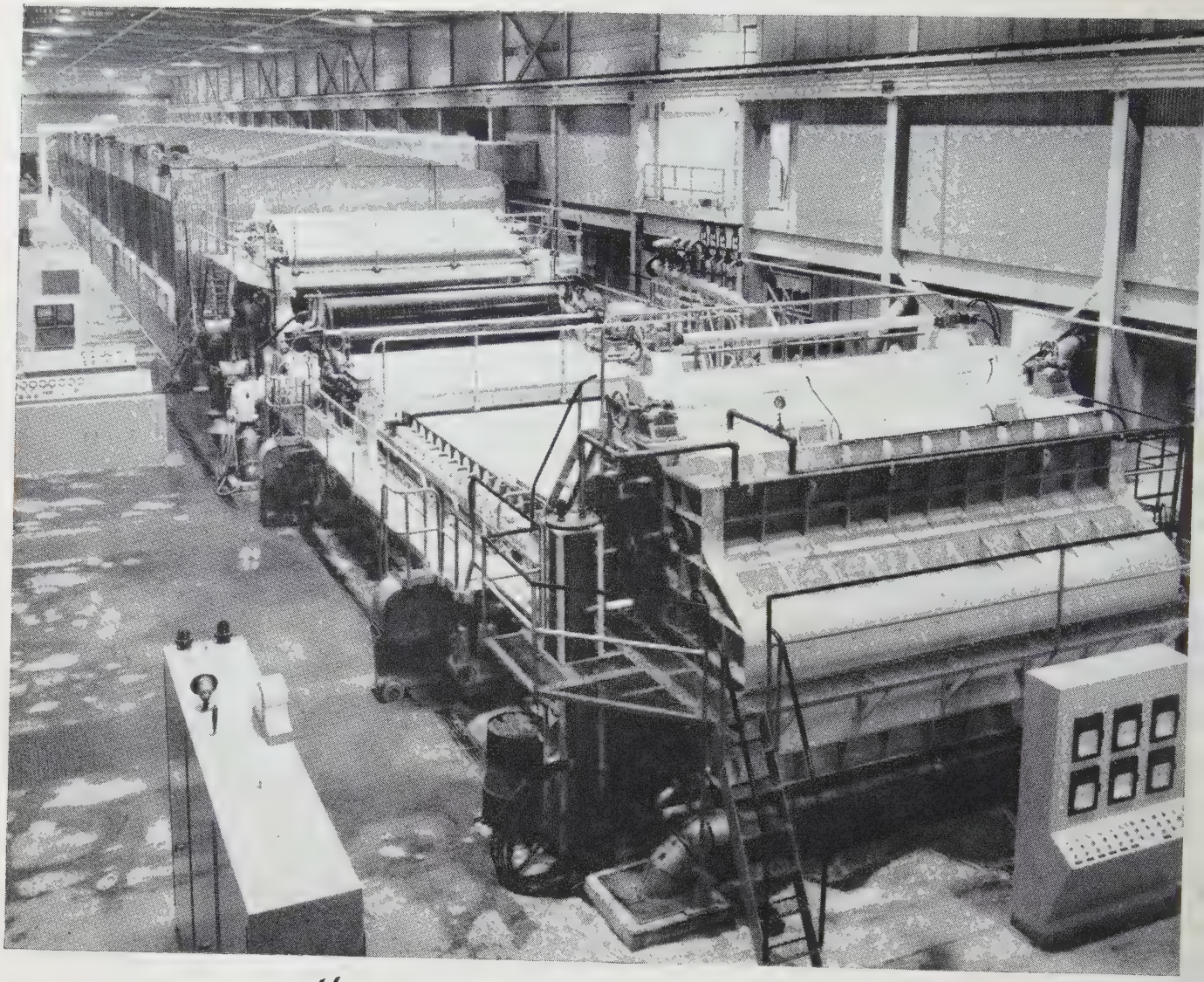

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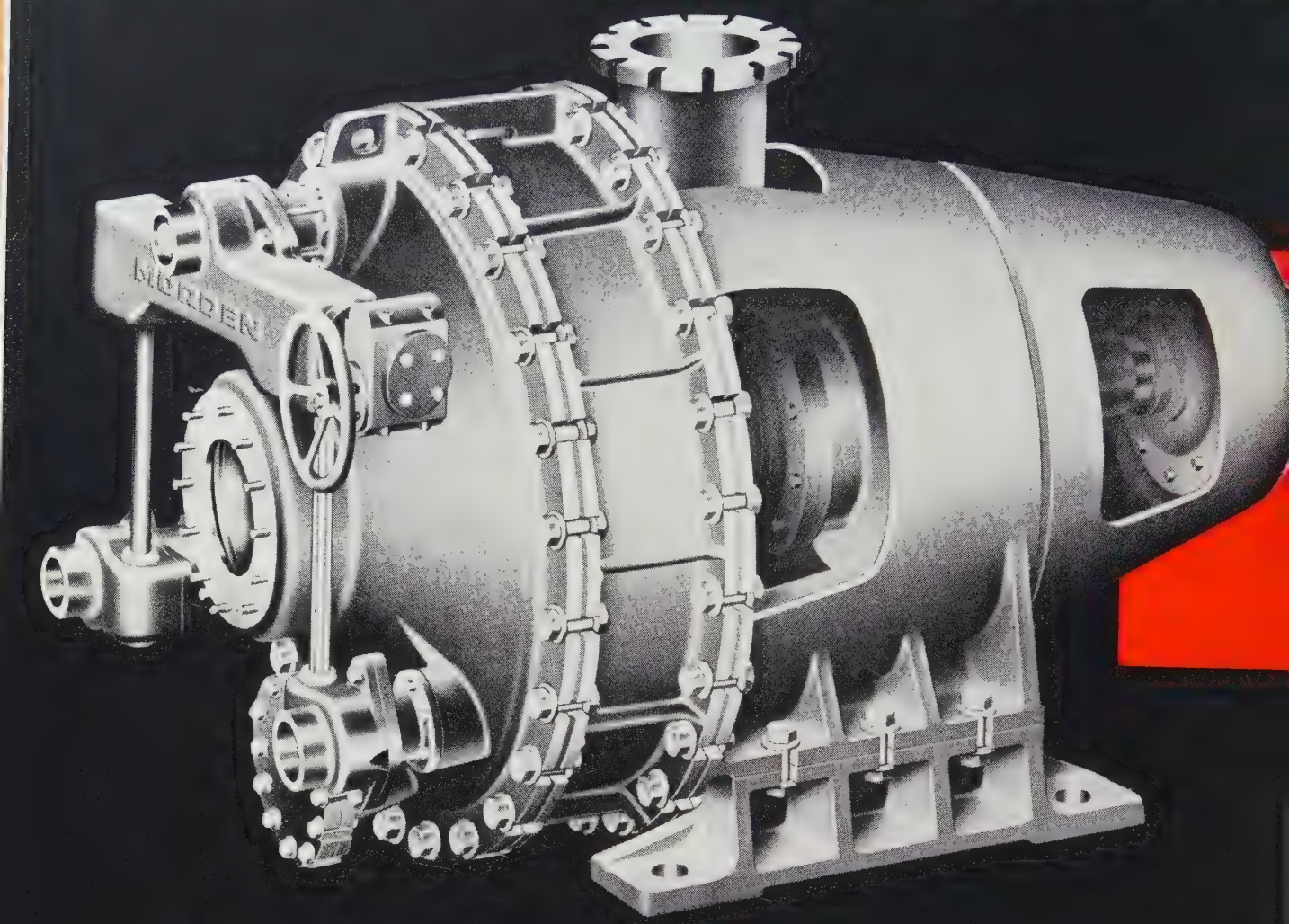


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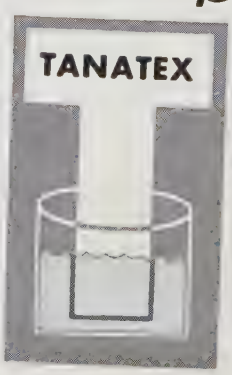


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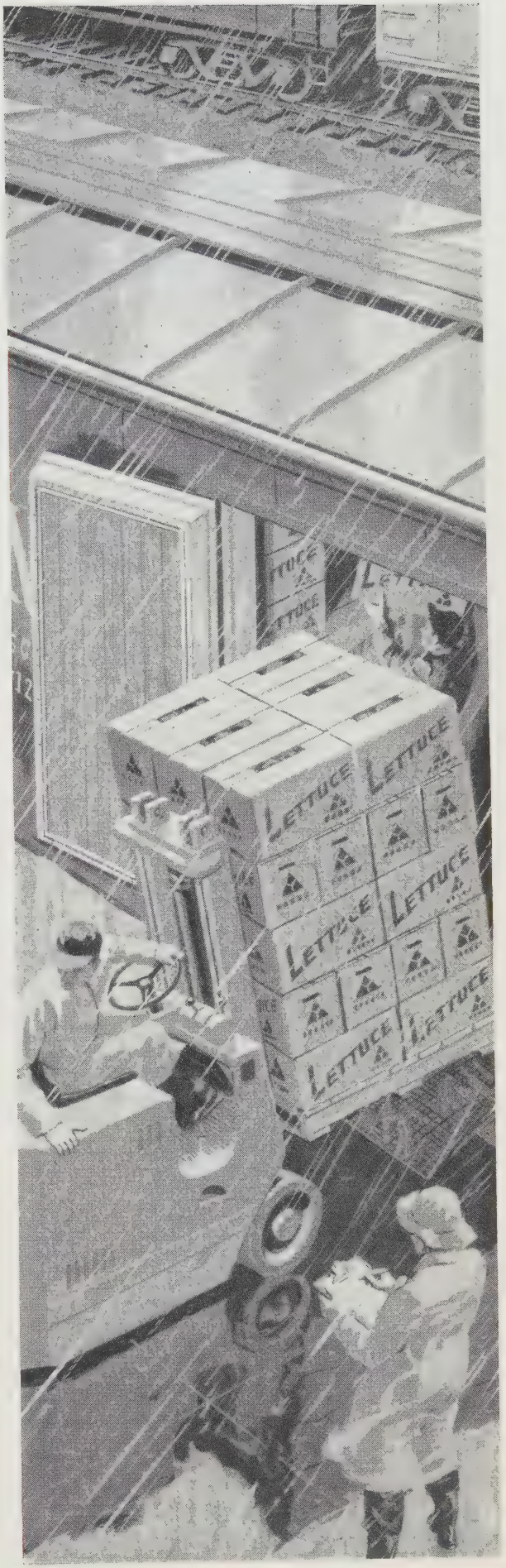


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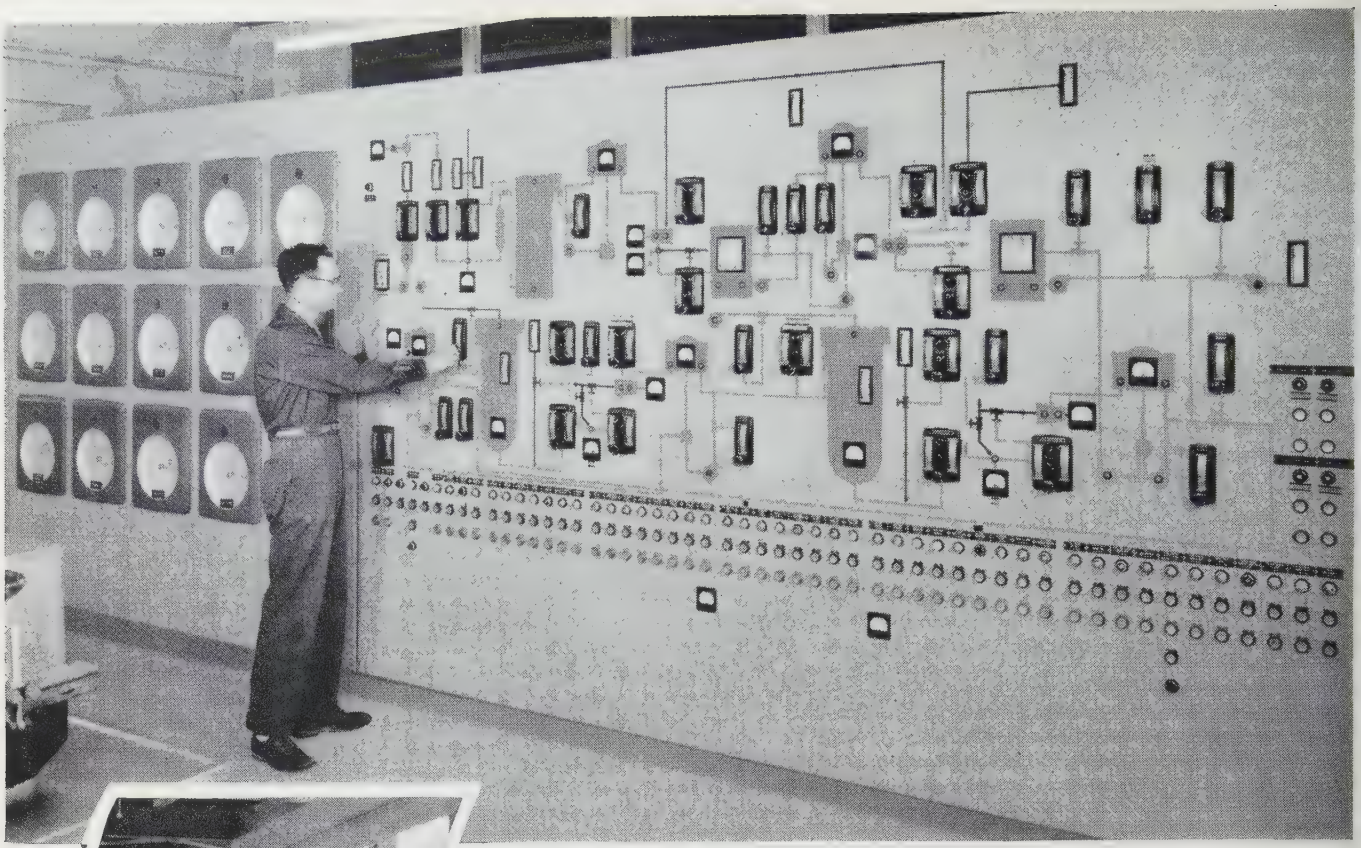

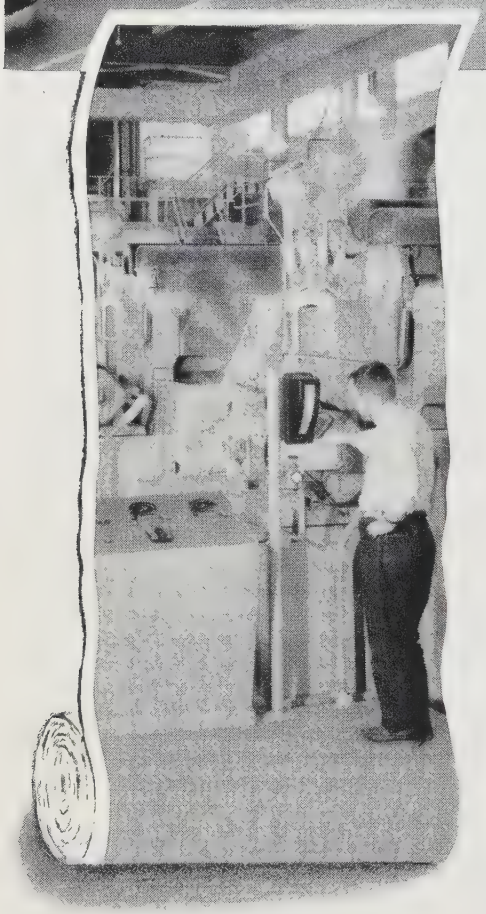

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# Bailey controls Marathon's five-stage bleach plant!

Marathon Southern's five-stage bleach plant at Naheola, Ala., is one of the most completely instrumented in southern U.S.A.

Rigid quality control—automatic and foolproof—keeps production going at top speed with unvarying excellence in the finished product.

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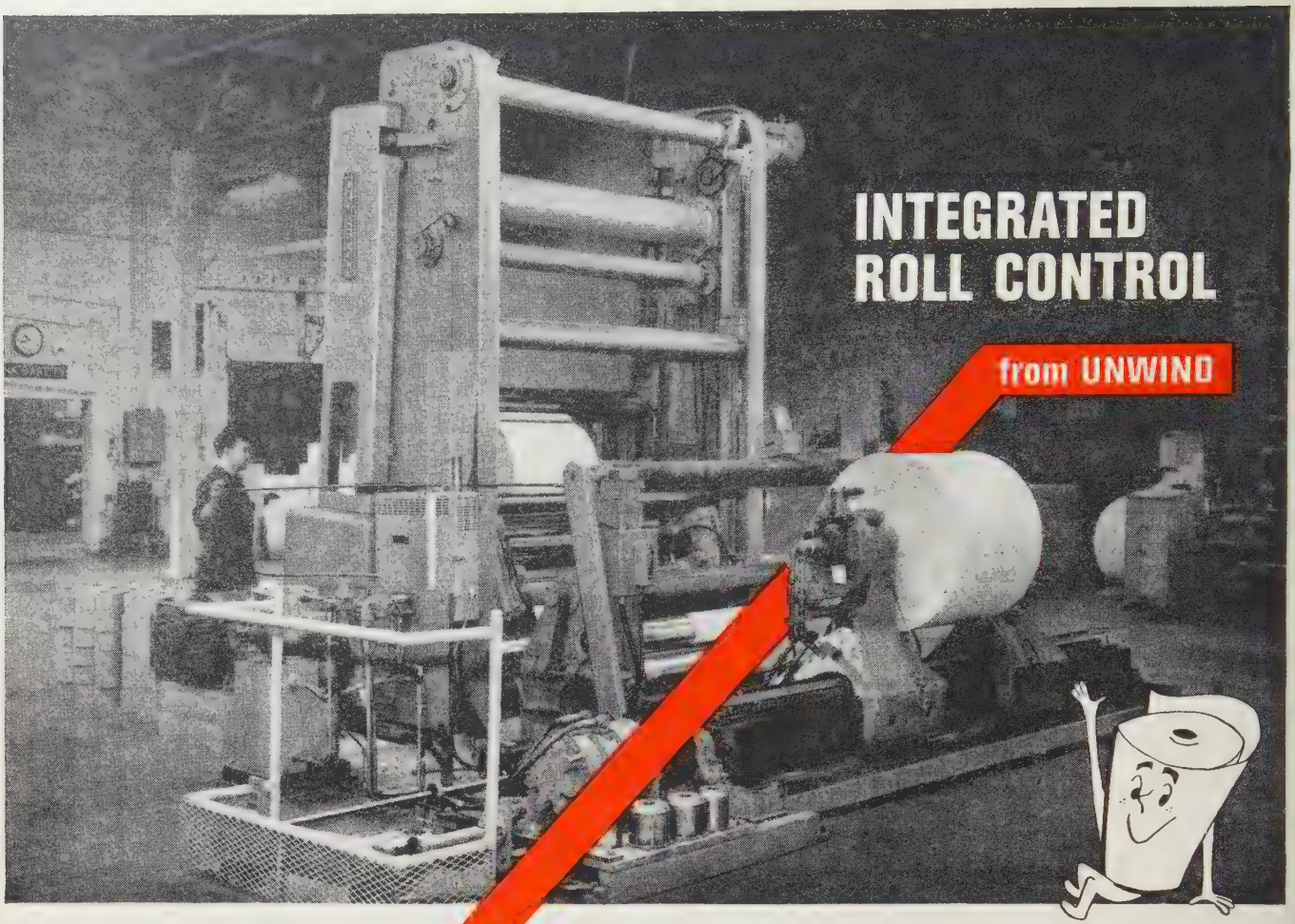


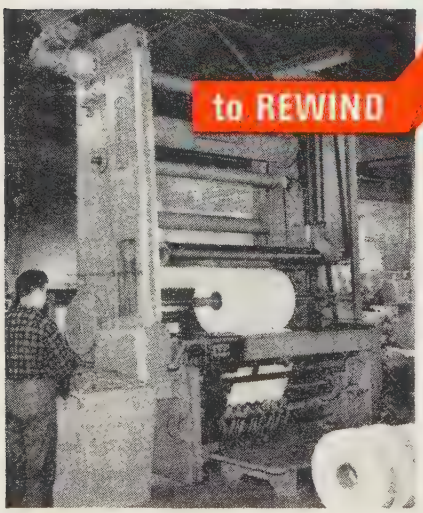


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# Drier Roller Bearing Lubrication

F. J. SULLIVAN and J. R. LYMAN

**This investigation was undertaken to determine the cause and to find a remedy for the large number of drier roller bearing failures that had recently occurred. A thorough examination of a representative group of failed bearings indicated a common factor of corrosive pitting. An extensive and varied testing program showed that antioxidant, detergent and dispersant oils were far superior to turbine type and straight mineral oils in preventing corrosion under wet conditions, as well as being able to clean up the residue of improper operation. The softening of bearing steels at temperatures above 300°F. indicates an upper limit for the operation of present day bearings.**

In the normal operation of roller bearings, some failures are to be expected due to so-called fatigue of the bearing metal. The rated life of a bearing is given by Allan (*1*) as the number of revolutions at a given load that 90% of a group of bearings will exceed before the first perceptible sign of fatigue appears.

Following World War II, and accompanying the increases in speeds and steam temperatures which took place at the time, there was a sudden increase in the frequency of drier roller bearing failures. Murray (*2*) described the characteristics of the failure which was labeled "pickup." The condition was alleviated by the use of oxidation inhibited, dispersant and detergent type oils. Langworthy and Weetman (*3*) have correlated the improved performance of these oils with their film strengths.

It can be anticipated that machine speeds and steam temperatures will continue to increase. This investigation was undertaken with the objectives of determining the causes of drier roller bearing failures and the methods of removing them so that failures similar to those mentioned above would not recur in the future.

## STUDY OF FAILED DRIER BEARINGS

A country-wide survey of failed drier roller bearings was undertaken. Papermakers of the United States and Canada contributed over 60 bearings in various stages of failure to the investigation. A portion of them are shown in Fig. 1. Of these, 10 were selected as typical of the type of failure involved and were thoroughly examined.

It was necessary to construct a special cutting machine to prepare specimens of the cumbersome bearings for examination. Other equipment used was a surface finish analyzer, a microhardness tester, a Faxfilm surface projection kit, and a conventional metallographic laboratory.

The examination of failed bearings from the mills first determined their general metallurgical and manufactured characteristics. The specific factors measured were bearing clearance, surface finish, hardness, and microscopic inclusions in the steel.

Secondly, the examination attempted to establish the general characteristics of the environment in which the bearings operated. The factors used to measure these were: bearing load, machine speed, steam pressure on the drier, size of the drier rolls, kind of lubricant, and its temperature entering and leaving the bearing, The geographical location of the machine on which the failed bearing was used was also noted.

The third phase of the bearing examination was to catalog the characteristics of the race surface and substrate macroscopically and microscopically. This was done with the optical microscope, microhardness tester, and x-ray diffraction apparatus.

The drier roller bearing failure with which this investigation was concerned had been characterized by so-called "pickup" and discoloration of the bearing surfaces. By "pickup" was meant the apparent removal of small particles from the contact surfaces. The discoloration was generally bluish-black on the contact surfaces and brown elsewhere on the bearings.

Fatigue failure originates below the contact surface of the bearing metal. Jones (*4*) has shown that the original martensitic structure of the metal is tempered by subsurface shear strain energy. This softening causes a weakening of the metal and eventual failure.

*Fig. 1. Failed drier bearings provided for the investigation*

F. J. Sullivan, Associate Professor of Mechanical Engineering, and J. R. Lyman, Associate Professor of Mechanical Engineering, University of Maine, Orono, Me.

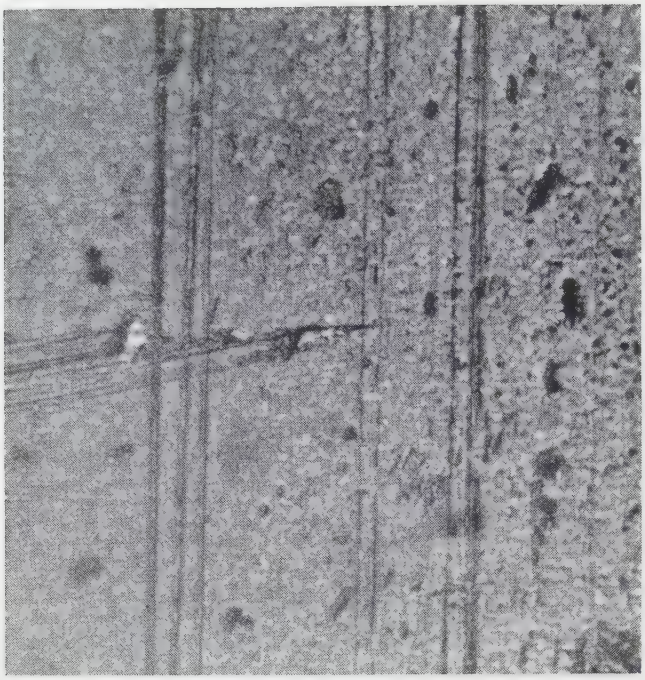

*Fig. 2. Contact surface of load area of drier bearing showing pits (250×)*

Many microhardness traverses of cross sections were made in the load areas of the bearings to discover any indications of subsurface softening. None of the examined bearings had failed due to the fatigue process. Even bearings that had relatively high inclusion content in the fatigue initiation zone of the substrate, as compared with an industrial standard, failed to exhibit the beginnings of normal fatigue despite the presence of these stress concentration locations.

An attempt was made to evaluate the original surface finish of the bearings by using the surface analyzer on well-cleaned unworn portions of the bearing surfaces. The average readings ranged from 8 to 22 microin. No correlation could be found between these measurements and the endurance of the bearings.

A variety of stained bearing surfaces was submitted for x-ray diffraction analysis. The stains ranged from yellow to brown to blue to black. As far as could be determined, the stains consisted of various forms of the oxides of iron.

Most of the bearings showed pitting on the uncontacted parts of the bearing surfaces; for example, the outer race between the two rows of rollers. Occasionally, as shown in Fig. 2, pits appeared on the contact surfaces. This indicated that corrosive action had taken place. The contact stresses in a roller bearing are high under usual operating conditions. Timoshenko (*5*) has shown that the existence of pits in the contact region will cause extremely high stress concentrations which in turn will result in early failure of the bearing.

All drier rolls are designed with some device to provide that the front or tending side bearing will be floating to take up the axial motion or the roll. Of the double row of spherical bearings examined, a few showed complete failure on one row and minor failure on the other, and some had a wear path around the outer race considerably longer on one row than on the other. It appears that these bearings were supporting heavy thrust loads.

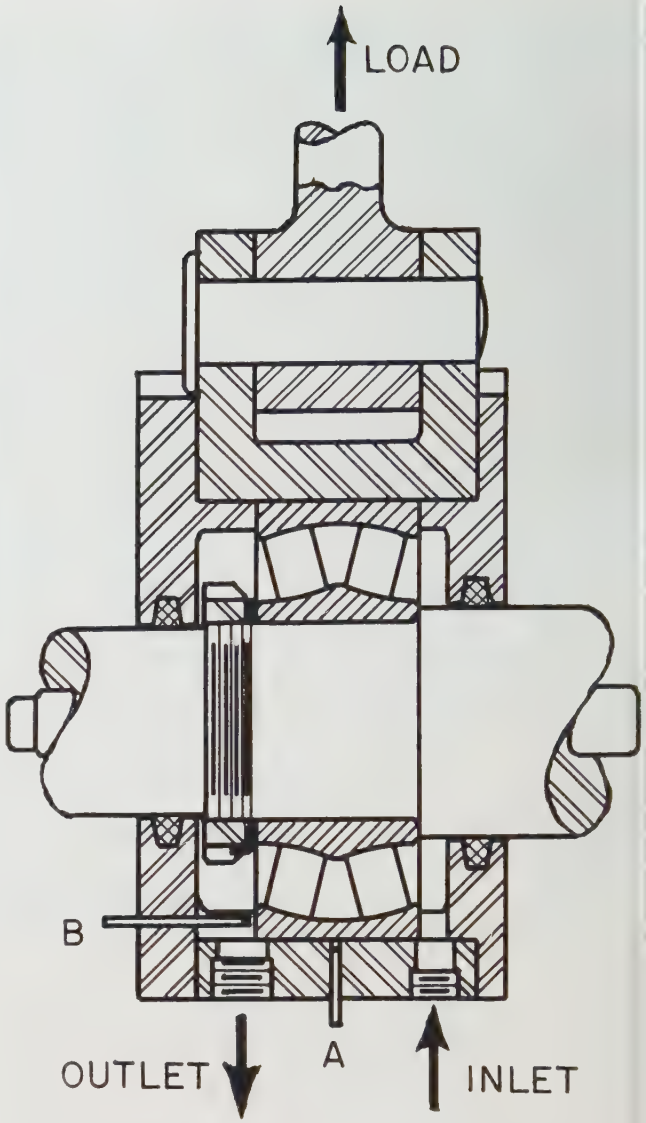


*Fig. 3. Diagram of bearing and housing on test machine*

## TEST EQUIPMENT

Two testing machines were designed and built to reproduce the conditions that were assumed to exist in drier bearings. The machines were modifications of a standard bearing testing machine. The loading system was inverted so that the load would act at the bottom of the test bearings and the housings were built for a circulating oil system. Two size-09 spherical roller bearings were used as test bearings on each machine. Electrical cartridge heaters were inserted in the shafts and supplied power through a slip ring arrangement. The details of one test bearing housing are shown in Fig. 3.

Each test bearing was to support a load of 5000 lb. with shaft speed of 975 r.p.m. This speed corresponds, on the basis of constant product of shaft diameter times r.p.m., to a rotating speed of over 200 r.p.m. on a full-size drier bearing or a linear speed on a 5-ft. drier of over 3000 f.p.m. The corresponding load on a full-size bearing for an equal life would be about 75,000 lb. The loads reported on the failed drier bearings averaged 20,000 lb., hence the test bearings were nearly four times overloaded.

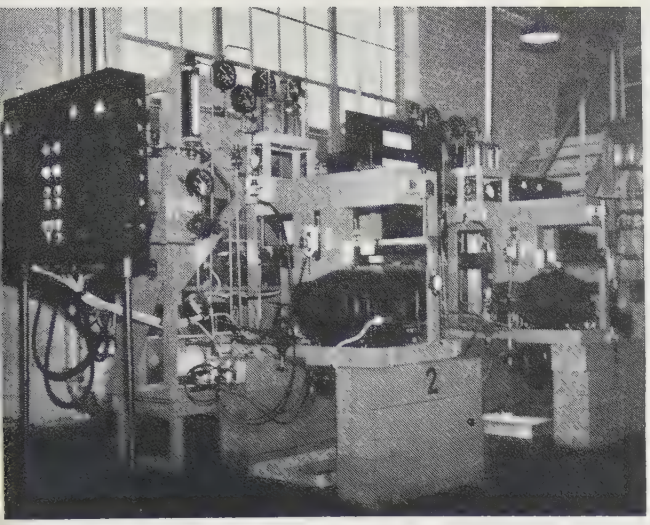

*Fig. 4. Arrangement of testing machines*

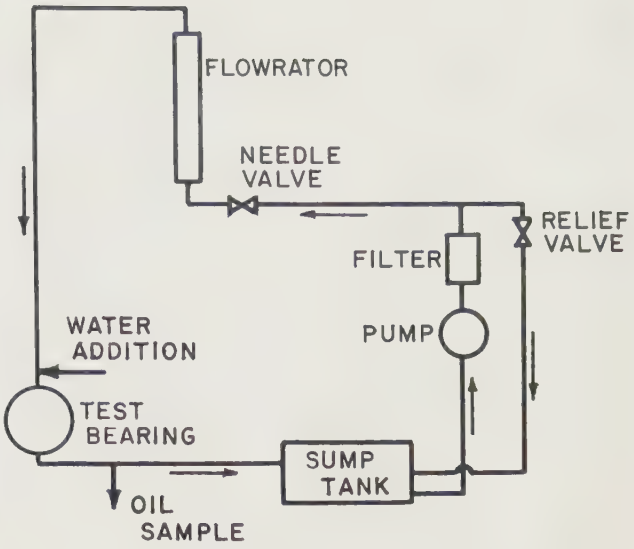


*Fig. 5. Diagram of lubrication system*

Each test bearing had a separate lubrication system. The original system was made with iron pipe, iron globe valves, and a sump and supply tank. Care was taken to keep copper or brass fittings out of the system to avoid the catalytic action of copper on heated oils. The oil flowed through a 4-ft. gravity head from the supply tank through a globe valve and flowrator to the test bearing. A loop in the system took oil from the sump tank through a paper filter to the supply tank from where an overflow line returned it to the sump tank. An electrical heater under the supply tank was controlled by a thermostat to maintain the oil temperature at 150°F. The input to the shaft heater was controlled by a rheostat. Wattmeters in the heater circuits measured the heat input.

A control system was designed that would completely shut down the machine in case of bearing failure. A 12-v. safety circuit, when opened, performed this function. In series in this circuit were adjustable thermostats attached to the outside of the bearing housings, the contacts of an adjustable relay whose coil was in series with the field of the main drive motor, and supplementary contactors on the oil pump motor starters. Any increased load on the drive motor, overheating of the bearing housing, failure of a motor, or temporary loss of power would shut down the machine.

Four temperature readings were taken at each test station: inlet and outlet oil temperatures and the bearing side and bottom temperatures. The latter two thermocouples were welded directly to the bearing outer race. In Fig. 3, at *A* and *B* are shown the ceramic insulators which brought the thermocouple wires through the housing. Temperature readings were recorded on a 16-point temperature recorder.

The adjustable relay with coil in series with the drive motor field was provided to shut down the machine when the current increased due to the larger load incident upon the failure of a bearing. The sensitivity of this device and the thermostats mounted on the housings varied considerably and a few times a failed bearing became extremely hot before the machine shutdown. To correct this situation, a device called a bearing monitor was installed. Thermocouples were welded to the sides of the test bearings and led to this instrument. If a bearing temperature rose above the temperature which had been preset on the bearing monitor, the instrument acted to break the safety circuit and to shut down the machine.

Gravity flow and globe valves proved to be completely inadequate to control the oil flow to the bearings. A relief valve set at 20 p.s.i. was inserted after the filter and a stainless steel needle valve by-passed oil through the flowrator to the bearing. It was necessary to disassemble the piping in order to flush the system completely between tests. Because of the difficulty and time involved in this procedure, the iron piping was replaced by steel tubing and stainless steel fittings. At the same time, the supply tank was removed and the heaters placed under the sump tank. A view of the machines after this alteration is shown

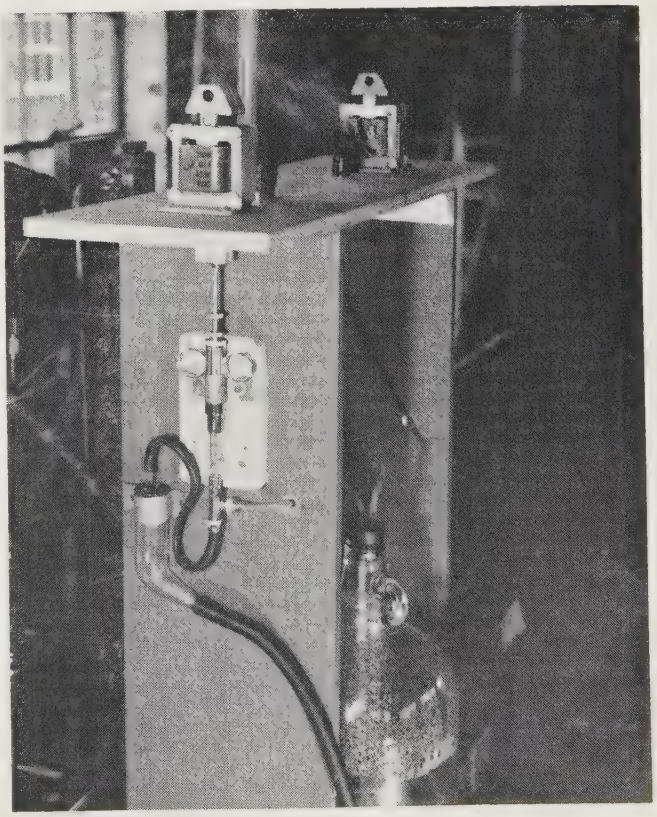

*Fig. 6. Arrangement of distilled water injection system*

in Fig. 4 and a diagram of the lubrication system is shown in Fig. 5.

From the early stages of the test program, it was desired to put a small amount of distilled water in the lubricating oil in order to simulate the contamination of the oil by condensed steam which is quite likely to happen in actual paper machines. Initially, a glass petcock was used to allow a few drops per minute to pass into the inlet oil line. This arrangement was quite unreliable. Finally, a system was devised which is shown in Fig. 6. The syringe is a multiple dose injection device used by bacteriologists to inoculate a large number of plates from the same solution. It can be adjusted to deliver from 0.1 to 2 ml. per stroke. The syringe was driven by a solenoid which in turn was actuated by a timer.

## BENCH TEST PROGRAM

The first tests on the machines were planned using a 4000-lb. load on each bearing and an oil which had previously proved to be unsatisfactory in paper machine operation. Several initial difficulties were encountered in the machine operation. The original shafts were not made to specifications and one failed due to fatigue very soon after starting. It was necessary to reduce the load on the bearings until satisfactory replacements were obtained.

The objective of the early tests was to produce gross failure in the test bearings. After runs of extended duration, only nominal wear showed on the test bearings. Since the examination of failed drier bearings had indicated that corrosive pitting was the source of failure, the next procedure was to rust the bearings in water before applying them to the testing machines. These tests, which ran for varying lengths of time, were inconclusive in that the precorrosion did not induce any further bearing deterioration. Finally the tests were operated adding 0.5 ml. of water per minute directly in the bearing supply line and running the tests over a period of time with off-on cycles each 24 hr. A few major failures occurred but these seemed to originate at a highly stressed edge of the inner race roll path.

It was observed during these tests that the oil became quite cloudy during the runs and there was no indication of localized corrosion of the bearing due to water collecting on the metal surfaces during the off periods. Further investigation showed that the formulation of the oil had been changed from the straight mineral oil that it had been when in unsatisfactory paper mill service to one with emulsifying properties. The tests using this oil were discontinued and a straight mineral oil, Oil A of Table I, was used in its place. At about this time, the manufacturer redesigned the test bearings, removing the sharp inner race edge which had failed previously. The new style bearings were used in all further tests.

In the cyclic type test the major bearing surface deterioration occurred in the first 8 days of the run. It was therefore decided to establish a standard testing procedure. Tests were started on Tuesday mornings. The machines operated 8 hr. daily, were shut down overnight, Saturday, and Sunday and the test was concluded the following Thursday afternoon. Each test bearing supported a load of 5000 lb. at a shaft speed of 975 r.p.m. In most of these tests, the oil

**Table I. Properties of Test Oils**

| *Oil →* | *A* | *B* | *C* | *D* |
|---|---|---|---|---|
| *Description of oil →* | *Straight mineral oil* | *Rust- and oxidation-inhibited turbine oil* | *Oxidation resistant, detergent, and dispersant oils* | |
| Tests | | | | |
| Gravity, API | 28.4 | 27.6 | 25.9 | 26.1 |
| Flash, COC, °F. | 460 | 475 | 480 | 460 |
| Viscosity, SSU | | | | |
| at 100°F. | 571 | 679 | 703 | 654 |
| at 210°F. | 66.2 | 69.7 | 70.6 | 67.6 |
| Viscosity index | 92.7 | 85.9 | 85.1 | 81.2 |
| Color, ASTM | 3 | 2 | 7 | 8 |
| Pour, °F. | 10 | 0 | 5 | −5 |
| Ash, % | Trace | None | 0.24 | 0.36 |
| ASTM rusting tests | | | | |
| Distilled water | Fail | Pass | Pass | Pass |
| Salt water | Fail | Pass | Pass | Pass |

flow was adjusted to maintain the outer race temperatures between 200° and 210°F. with a shaft heater input of 115 w. In addition to the distilled water which was added to the lubricating oil during the running period, at the conclusion of each day's run $^1/_2$ oz. of wet steam was injected directly into each test bearing housing when the test bearing temperature had dropped to 150°F. Using these techniques, a series of tests was made evaluating Oils A, B, C, and D of Table I.

On a few occasions from the beginning of the program, bearings had seized because of the inadvertent failure of their oil supply. Parenthetically, a few of the failed paper mill bearings had discolorations and failure patterns quite similar to these. Since a repeatable and reliable pattern had been established for the four oils following the ten-day period cyclic runs, it was decided to observe the bearing's behavior with an oil starvation period appended to the cyclic runs. On Thursday afternoon of the tenth day of the cyclic run, the oil supply line to the bearing housing was disconnected and the shaft heater input adjusted so that the bearing temperature stabilized at either 250° or 300°F. maximum. The bearing monitor was set to shut down the machine upon a temperature rise of 25°, which suddenly occurred after the bearing had been running steadily for a number of hours.

## RESULTS

The early part of the testing program provided considerable information regarding the operation of bearings under a variety of conditions. It was not until after the adoption of the 10-day cyclic run and the oil starvation period that reproducible and satisfactory data were obtained to evaluate the performance of the oils under test. All parts of the bearings were examined after the tests. However, since the outer race was stationary, had contact and uncontacted areas, and had its temperature continuously recorded, this element of the bearing was given the most careful examination. The results of the tests are summarized in Table II.

A light bluish stain was observed in the contact areas of the bearings after a 10-day cyclic run using Oil C. A similar strain in the contact areas existed after using Oil D, but also a lighter blue overall stain was found on all exposed areas. Other than the rust blotches, Oils A and B showed little or no discoloration. Efforts were made to take color photographs of these various

Table II. Summary of Test Results

| | A | B | C | D |
|---|---|---|---|---|
| | | Ten-Day Cyclic Run | | |
| Discoloration | Heavy rust blotches | Occasional light rust blotches | Light blue stain in load areas | Overall light blue-green stain |
| Pitting and roughening | Heavy | Some severe pitting in load areas | Occasional pinhead pits in load areas | Occasional pinhead pits in load areas |
| Deposits | Rust | Negligible | None | None |
| | | Oil Starvation Run | | |
| Discoloration | Golden to tan varnish stain | Brown stain, rust blotches | Coppery stain. Occasional slight black stain. Occasional rust spots | Slight light-tan stain |
| Pitting and roughening | Heavy | Roughening and moderate pitting | Occasional pinhead pits in load areas | Occasional pinhead pits in load areas |
| Deposits | Brown gum and black carbonaceous deposits. Black rust | Black gummy carbonaceous deposit | Brown gum. Hard black carbonaceous deposits | Soft and hard carbonaceous deposits. Oily brown gum |
| Appearance after relubrication | Deposits partially removed | Not observed | Not observed | Rehabilitated |

stains, but the coloring was too subtle to be able to be reproduced.

The oil flow maintained during the tests ranged from one fifth to one quarter of a pint per minute. On an equivalent area basis, this would compare to about four pints per minute on a full size bearing. The flow required during the first part of a run was somewhat higher, which could be attributed to the wearing in of the bearings. Small variations in oil flow from run to run were probably caused by slight differences in the manufacture of the bearings and changes in the tightness of the bearing housing seals.

The bearings which had seized at the finish of an oil starvation run were filled with a heavy brown gum and black carbonaceous deposits of varying degrees of hardness had formed on the contact surfaces. A few tests were made relubricating bearings after they had failed. Oil D almost completely removed the deposits and other than the slight galling and scarring of the surfaces which occurred at seizure, the bearings had the appearance of those which operated on the regular cyclic run. Bearings relubricated with Oil A operated somewhat more roughly and the hard carbonaceous deposits were not removed.

In the starvation runs, the time elapsed between shutting off the old supply and seizure of the bearings varied widely for each oil. It appeared from the evidence of a very few tests that 250° starvation operation permitted a longer running period. The averages of time to failure for the various oils were not appreciably different.

In a series of oil starvation runs at 300°F., after using Oil C it was observed that, of the two test bearings on the machine, the one which operated the longer time above 300°F. invariably seized first. Because of the difficulty of the shaft heater adjustment, there was nearly always a few degrees difference between the two bearing temperatures.

During a test on one oil, which was used only once and therefore not otherwise reported upon here, a tight emulsion formed in the oil. The oil flowing through the flowrator was markedly nonhomogeneous and the filter clogged. The emulsion was believed to have formed because, due to a defective thermostat, the supply tank temperature dropped from 150° to 130°F.

A series of 2-hr. annealing tests was carried out on specimens of steel from the races. The results are plotted in Fig. 7. These showed that the metal retained its original hardness up to 300°F. at which point the hardness began to decrease. Many microhardness tests were made on the test bearings, and in no case was there indication of a softening of the metal.

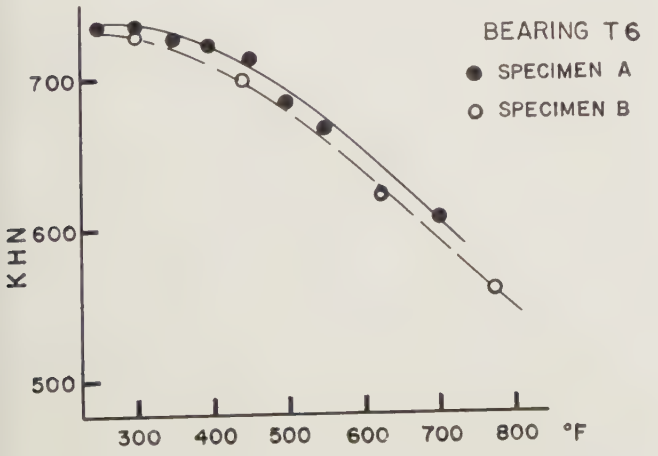


*Fig. 7. Knoop hardness number (500-g. load) of bearing steel specimens after tempering 2 hr. at various temperatures*

## CONCLUSIONS

The examination of actual failed paper machine bearings showed that corrosive pitting had taken place on all of them. The protection of the surface to prevent the formation of these stress concentration locations and the origin of surface failures should remove the source of the "pickup" type of drier bearing failure.

Because of the nature of its operation, it can be expected that the circulating lubricating oil of a paper machine drier will pick up moisture. To prevent the accumulation of water in the system, an adequately sized settling tank must be used. Secondly, an antioxidant, dispersant, and detergent oil will provide protection in case the oil should become contaminated with water.

A light-bluish stain of the bearings accompanies the use of the better oils. A dark brown stain and carbonaceous deposits on the bearing surfaces indicates

that the bearing has overheated, which can be caused by cutting off the bearing's oil supply.

The 10-day cyclic run enabled the evaluation of the protective qualities of the oil tested. The oil starvation period was superimposed on the run to measure the lubricating qualities of the oil under extreme conditions. The slightly poorer performance of Oil C compared to Oil D is attributed to some component additive which became unstable at the elevated temperature of the starvation run.

The fact that the present conventional bearing metal cannot be heated above 300°F. without softening sets a limit to the operating temperature of drier rolls. There is no available information as to the actual temperatures of operating bearings but they can be assumed to be somewhat less than drier steam temperatures. Since some machines are now operating with 350°F. steam, some metallurgical problems may be anticiplated as temperatures increase in the future.

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# Simulation of Pulpwood Inventory Dynamics in the Operation of an Integrated Pulp and Paper Mill


THOMAS A. HEWSON



**A pulpwood inventory will fluctuate in size because of uncontrollable variations in production, weather, labor, transportation, the availability of stumpage, and other factors. The size of a pulpwood inventory at any time should be large enough to tolerate subsequent variations downward without running out of wood. On the other hand it is impractical to carry an inventory large enough to guarantee a supply of wood under catastrophic circumstances. A pulpwood inventory should properly be proportional to the risk which management is willing to accept in the face of uncertainties in procurement and production. The risks associated with different size pulpwood inventories have always been difficult to evaluate and express in meaningful terms. A pulpwood supply and demand situation is simulated by means of a mathematical model. Uncontrollable elements of the complex are replaced by probability distributions. The model is programmed for a computer and simulated operational data are obtained for extended periods of real time. The nature and extent of inventory fluctuations are investigated. The model is altered to test the response of different inventory policies, production levels and procurement procedures. The risks associated with various operating policies and procedures are quantified.**


Pulpwood inventory is a vital and complex part of the papermaking process. A paper mill must not run out of pulpwood. On the other hand it is impractical to carry an inventory large enough to guarantee a supply of wood under catastrophic circumstances. A pulpwood inventory should properly be proportional to the risk which management is willing to accept in the face of uncertainties in procurement and production.

The risks associated with different size pulpwood inventories have always been difficult to evaluate and express in meaningful terms. In the past, the situation has been dealt with primarily on the basis of empirical practices developed over the years. Many companies have knowingly adopted a better-safe-than-sorry attitude, whatever the cost. These facts coupled with continuing pressure to reduce costs wherever practicable have indicated a need for a better understanding of pulpwood inventory dynamics and some quantitative measure of the risks associated with various inventory levels under specified operating conditions.

A mathematical model can be constructed of a pulpwood supply and demand system which will simulate, in a probabilistic sense, operational data in real life. Using the model it is possible to measure the risks associated with various inventory levels and to evaluate the effect of alternate inventory policies, production levels, and procurement procedures on plant operations without assuming the financial burden and risks of interrupting mill operations in real life. Moreover, the mathematical pilot plant can be operated for extended periods of real time in order to expose proposed operating policies and procedures as well as contemplated changes in production capacity to the full range of effects of weather, labor, transportation, stumpage, machine schedules, etc., which are likely to be encountered in real life. This report will illustrate the construction, operation and analysis of a mathematical model of a real pulpwood supply and demand system in one of St. Regis' integrated pulp and paper mills.

## PRODUCTION AND PROCUREMENT OPERATIONS

In any papermaking operation, the nature and extent of the demand for pulpwood is determined by the requirements of the paper machines. It is normal to expect week-to-week fluctuations in consumption, excluding shutdowns and holidays. These fluctuations are caused by the product mix, variation in number of paper breaks, repair and maintenance, and other changeable factors inherent in the process.

The object of the procurement function is to obtain good quality wood and chips, as cheaply as possible,


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in required amounts at the proper time. Unpredictable variations in the rate of flow of pulpwood and chips to the mill are caused by changes in weather, labor, transportation, the availability of stumpage and other factors.

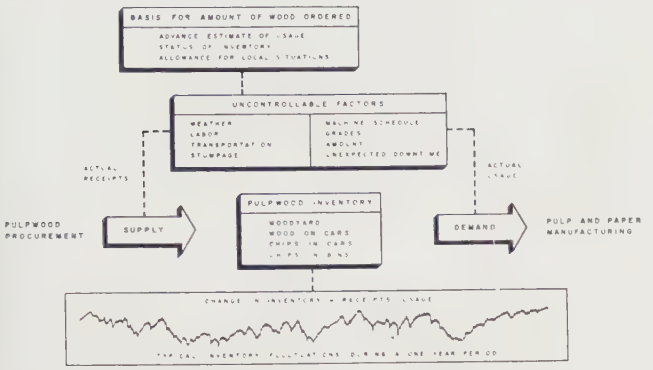


*Fig. 1. Schematic diagram of pulpwood operations system*

A schematic diagram of the system is given in Fig. 1.

## DEVELOPMENT OF THE MATHEMATICAL MODEL

A model to simulate the dynamic behavior of a pulpwood inventory must necessarily incorporate the unpredictable factors in production and procurement which are experienced in real life. This is accomplished by using the Monte Carlo method wherein unpredictable factors are selected at random from probability distributions of these factor values; and the solution is repeated a sufficient number of times to express the answer as a probability function. In developing the model to simulate real life, the same logic and sequence of events are reproduced.

*In practice:* the procurement department orders wood from dealers weekly for shipment the following week. The amount ordered is based on forecasts of usage, local weather, labor situations, stumpage, and whether or not the current inventory level is above or below a specified range. The amount of wood received in response to the order is influenced by the *actual* weather, labor, transportation, and availability of stumpage. The effect of these unpredictable factors on the response to the order will also vary at different times during the year.

*In the model:* wood orders are composed. The amount of wood ordered is based on advance estimates of usage, the status of inventory with respect to some established policy, and a forecast of current situations such as weather, labor, and stumpage. The amount of wood actually received in response to these orders is then determined. This of course depends upon the simulated actual weather, labor, transportation, and stumpage conditions that prevail at the time. Seasonal trends are also taken into account but catastrophic circumstances are not considered. Finally, the actual wood usage is determined on a weekly basis and suitable allowances are made for holidays, scheduled downtime, unexpected downtime, and normal variations in consumption caused by scheduling. Weekly data on wood receipts and usage are used in subsequent calculations to show inventory fluctuations, production and procurement histories, and values of other related variables of the paper manufacturing process. Sections of the model will now be presented in detail to aid in understanding their design and function.

### WOOD ORDERS

The amount of wood ordered in any one week may be evaluated by adding together the predicted usage for that week, an inventory allowance, and a situations allowance. This may be expressed in symbolic forms as follows:

$$\text{Wood ordered} = \text{Predicted usage} + \text{Inventory allowance} + \text{Situations allowance}$$

or

$$W_{0n} = P_{Un} + I_{an} + S_{an} \qquad (1)$$

Subscript $n$ is used to refer to a particular week of the year. For example, the wood ordered during the first week of the year is given by:

$$W_{001} = P_{U01} + I_{a01} + S_{a01} \qquad (2)$$

and for the last week of the year by:

$$W_{052} = P_{U52} + I_{a52} + S_{a52} \qquad (3)$$

In order to evaluate $W_{0n}$ over a 1-year period it is necessary to evaluate each of the constituents $P_{Un}$ $I_{an}$, and $S_{an}$ for 52 weeks. Another way of saying this is that values must be obtained for the following:

$$P_{U01}, P_{U02}, P_{U03} \ldots\ldots P_{U52}$$
$$I_{a01}, I_{a02}, I_{a03} \ldots\ldots I_{a52}$$
$$S_{a01}, S_{a02}, S_{a03} \ldots\ldots S_{a52}$$

The predicted usage for the mill under study on a weekly basis will normally be 12,500 cords. However, during weeks with scheduled downtime, Christmas, or Labor Day, predicted usage values will be proportionately lower. During a year it is also likely that there will be 4 or 5 weeks when lower consumption is anticipated because of extended runs on extreme basis weight papers. For purposes of simulation, predicted usage values for some weeks will be fixed in advance as follows:

| | | |
|---|---|---|
| $P_{U36}$ = | 10,500 cords | (Labor Day) |
| $P_{U52}$ = | 8,300 cords | (Christmas) |
| $P_{U7}$ = | 11,000 cords | (planned shutdown) |
| $P_{U20}$ = | 8,000 cords | (planned shutdown) |
| $P_{U33}$ = | 11,000 cords | (planned shutdown) |
| $P_{U46}$ = | 8,000 cords | (planned shutdown) |

Although the planned shutdowns are not scheduled this far in advance, every effort is made to schedule one shutdown each quarter. It is believed that exact timing within the quarter has a negligible effect on the range of inventory variations that will be produced by successive iterations of the model except under extraordinary circumstances. Predicted usage values for weeks other than the six listed above are obtained at random from the following table:

| *Random numbers* | *Predicted usage in cords* |
|---|---|
| 0–100 | 11,000 |
| 101–999 | 12,500 |

This value will simulate the predicted usage for any particular week of the year other than the six listed above. Accordingly values of 12,500 cords will be obtained approximately 90% of the time and values of 11,000 cords the remaining times. The random means used to select the predicted usage values during these 46 weeks, simulates the uncertainties in real life as to when extreme basis weight runs will be scheduled.

The inventory allowance may be defined as that portion of the wood order which is used to control the inventory size within a specified range or policy. In other words, if the inventory falls very low, the wood order should be increased above the value of predicted usage so as to bring the inventory back to the desired level. On the other hand, when the inventory builds

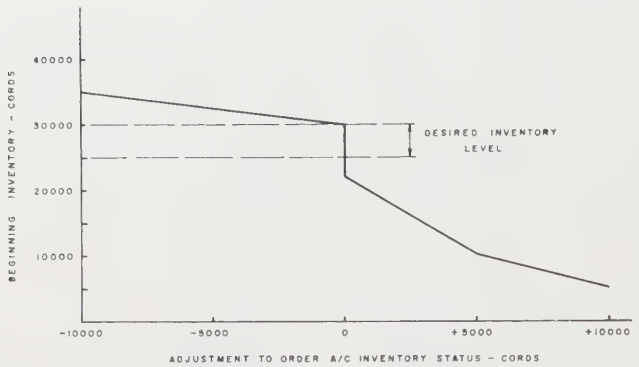


*Fig. 2. Inventory policy input function no. 1-B*

up excessively high, the wood order should be decreased below the value of predicted usage to diminish the amount of wood on hand. The amount of inventory allowance made for any particular week depends on the size of the beginning inventory for the same week. Accordingly, values of $I_{an}$ cannot be determined in advance. However, input function no. 1-B (see Fig. 2) can be used to evaluate $I_{an}$ as an interim calculation once the size of the beginning inventory is known. The function actually expresses inventory policy. Accordingly, changes in desired inventory level and policy may be introduced into the model by alternate inventory policy input functions.

The situations allowance may be defined as that portion of the wood order which is used to offset the effects of immediate weather, labor and competitive conditions that prevail or are anticipated at the time the order is placed. The amount of this allowance ranges from $-500$ cords to $+1500$ cords.

It is not known what particular value of situations allowance will be made by the procurement office in any given week. As a consequence, real life will be simulated by selecting a value at random from a histogram approximating experience in real life.

The procedure for composing wood orders that resemble the size and incorporate the logic of orders in real life should be clear from the foregoing discussions. This procedure can be repeated as many times as desired to reproduce the order history of a hypothetical plant for one or more years. In each instance, the exact size and sequence of orders will change within limits which are reasonable to expect in real life procurement operations.

## WOOD RECEIPTS

The amount of wood received in response to the orders must also be simulated. It is well known that weather, labor, transportation and the availability of stumpage affect procurement operations significantly. Moreover, the general level of response will vary during different seasons of the year.

The resultant effect of the unpredictable procurement factors on the ratio of receipts to orders during a certain period, may be expressed as a probability function.

For the model, procurement response functions were established with Woodlands personnel after individual and collective discussions with area procurement foresters and wood dealers. When sampled in a random manner, it is intended for these functions to produce simulated values of the ratio of receipts to orders. During evolution of the functions, it developed that some months were similar in procurement response. As a result, four functions cover all seasons of the year.

For the mill under study, there is a tendency during November, December, and January to receive more wood than is actually ordered. Labor is plentiful during this period; the weather is not too severe; and stumpage is readily available. There is also a strong incentive on the part of producers to make a little extra money for the Christmas holidays. Function 1-D, however, does provide for occasions where wood orders are not filled during this period. Adverse weather or other situations could account for ratios below 1.0; but it is more likely that values above 1.0 will occur as indicated from experience in real life and portrayed by the curve.

During February, March, and April, labor is generally poor because of tobacco and other farm planting in the wood procurement area. This period is also attended with rains that have an adverse affect on logging operations. The difficulties of procurement at this time are experienced also by other mills, and it is likely that competitive activity will further diminish the chances of receiving what is ordered. Accordingly, the ratio of receipts to orders during this period will average approximately 0.85. There is a small chance that during one or more weeks the receipts might be only 25% of the amount ordered. Conversely there is also provided a small chance that receipts might exceed orders by 25%. Function 1-E represents the limits and tendencies of procurement response that are considered to exist in real life for the procurement territories with acceptable freight rates to the mill under study.

In May and June, the labor situation improves compared with preceding months. However, stumpage is more difficult to come by, weather worsens and it is estimated that the average of procurement response during this period is approximately 0.90 as shown above. Function 1-F represents the response function for May and June. When sampled in a random manner, values simulating real life can be obtained for the weeks during this period.

July, August, September, and October are the most difficult months for procurement. Stumpage is very short because land owners are reluctant to have their timber cut for fear of insect infestation. Heat is often intense and rainfall can be very heavy. In addition, substantial segments of the labor leave for harvesting the crops which pay more. Competitors are also affected by these factors with the result that their procurement activities are stepped up; this again lessens the likelihood of St. Regis obtaining the wood it orders at a reasonable price. The ratio average for July through October is approximately 0.75. There is more tendency toward week-to-week variations during this period because of the number and extent of adverse

factors. Function 1-G is used to simulate real life on a weekly basis during July, August, September, and October.

When sampled in a random manner, the four functions discussed above will produce values of procurement ratio, receipts to orders, for every week of the year. Of course the appropriate function must be used de-

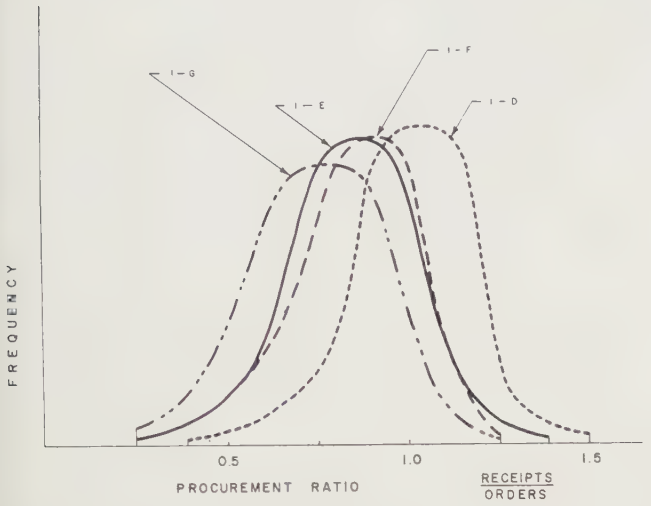


*Fig. 3. Procurement response functions covering all seasons of the year*

pending upon the particular week of the year. Let $P_{rn}$ represent the procurement ratio. Using the same subscript terminology as previously, $P_{r01}$ would signify the ratio value for the first week in January; and $P_{r52}$ the last week in December.

The amount of wood received in any week in response to the order $W_{0n}$, is represented by the symbol $R_{0n}$. The same subscript terminology applies so that over a year $R_{0n}$ has 52 separate values, designated as $R_{001}$, $R_{002}$, $R_{003}$ - - - - $R_{052}$. $R_{0n}$, the wood receipts-in-response to orders, can be evaluated by multiplying the corresponding wood ordered $W_{0n}$ by the procurement ratio $P_{rn}$. This can be expressed symbolically as:

$$R_{0n} = W_{0n} \times P_{rn} \tag{4}$$

Accordingly, the receipts-in-response-to-orders during specific weeks of the year can be obtained using appropriate wood orders and procurement ratios. For example:

$$R_{001} = W_{001} \times P_{r01} \tag{5}$$
$$R_{0C2} = W_{002} \times P_{r02} \tag{6}$$
$$R_{003} = W_{003} \times P_{r03} \tag{7}$$
$$\vdots$$
$$R_{052} = W_{052} \times P_{552} \tag{8}$$

It is recognized that all wood ordered for a particular week will not be delivered during that same week due to the distances involved and other factors. When the amount of wood ordered is within normal limits (inventory allowance does not exceed $\pm 2000$ cords) the procurement ratio probability distributions incorporate the delayed shipment effect. When the inventory allowance exceeds $\pm 2000$ cords, however, the excess is discounted from computations of $R_{0n}$ and added as a delayed shipment the following week. In real life it is not possible to shut off wood shipments immediately. It is also difficult to receive substantial quantities of wood above normal requirements without going to high freight rate areas, with consequential added costs and delivery delays. These real life situations are simulated by the procedure discussed above.

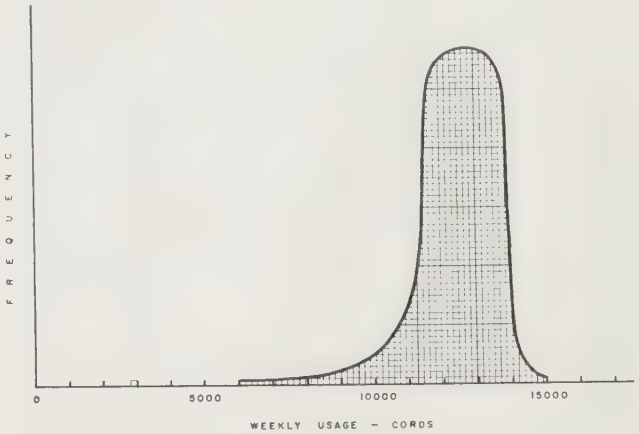


*Fig. 4. Probability distribution of actual usage input function no. 1-J*

The total wood received in any week, $R_{Tn}$, is evaluated by adding wood receipts-in-response-to-orders $R_{0n}$ and wood receipts-from-delayed-shipments $R_{dn}$. This may be expressed in symbolic language as

$$R_{Tn} = R_{0n} + R_{dn} \tag{9}$$

By combining equations (4) and (1), (9) may also be evaluated by:

$$R_{Tn} = W_{0n} \times P_{rn} + R_{dn} \tag{10}$$

or

$$R_{Tn} = (P_{un} + I_{an} + S_{an})P_{rn} + R_{dn} \tag{11}$$

Up to this point a procedure has been devised to simulate the amount of wood ordered and the amount of wood received during successive weeks of a year. Moreover, unpredictable factors of procurement and prediction are incorporated to the same extent believed to exist in real life. The amount of pulpwood consumed by the mill will now be considered.

## WOOD CONSUMPTION

Normal wood consumption for the mill under study is approximately 12,500 cords per week. It is utopian

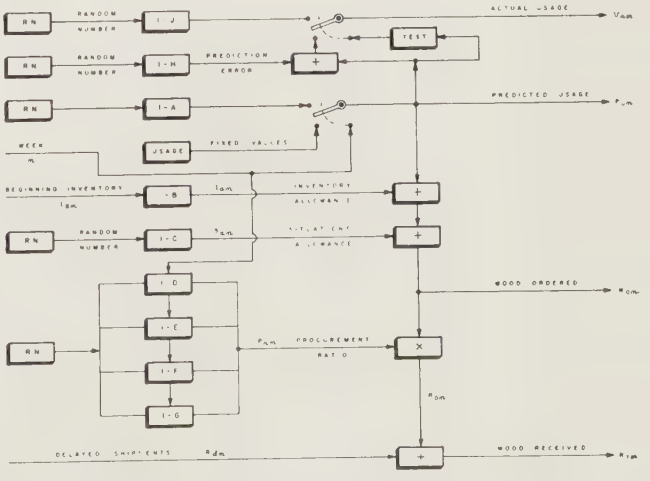


*Fig. 5. Schematic diagram of major elements of the mathematical model*

to believe that exactly 12,500 cords of wood are used every week of the year. The variations that actually occur are the results of holidays, planned shutdowns, long runs on extreme basis weight grades, scheduling sequence, and/or unexpected downtime. It is necessary to simulate these real life variations in the mathematical model. Since some reductions in production are anticipated beforehand, and incorporated into the predicted usage values for a particular week, it is reasonable to expect that within the range of prediction error a reduction in production will be experienced. The model follows the same logic in simulating weekly wood consumption. When the predicted usage of wood is below 12,500 cords, the actual wood consumption or usage for that week is determined by adding the predicted usage, $P_{Un}$, to the error of prediction $E_{pn}$. This statement may be expressed symbolically as:

$$U_{an} = P_{Un} + E_{pn} \; (P_{Un} < 12{,}500) \qquad (12)$$

where

$U_{an}$ = actual wood usage in cords for week $n$.
$E_{pn}$ = prediction error in cords as obtained from input function no. 1-H.

Prediction error data were obtained from records of past performance and discussions with production personnel. A probability distribution was then constructed. This distribution is sampled in a random manner to obtain values for use in simulating real life.

During weeks when normal operation is forecast, actual consumption for the mill will be in the range of 11,000 to 14,000 cords as shown by past experience. There is of course a chance, but a small one, that consumption might drop below 11,000 cords or exceed 14,000 cords. The probability distribution showed in

**Table I. Simulation of Operations at the St. Regis Mill—Model No. 1, Year 5, Weekly Operational Data**

| *Mo.* | *Beginning inventory, cords* | *Predicted usage, cords* | *Actual prodn., tons* | *Actual usage cords* | *Wood ordered, cords* | *Wood recd., cords* | *Ending inventory, cords* | *Inventory change, cords* | *Prediction efficiency* | *Procurement efficiency* | *Month range, cords* | *Extra wood cost, dollars* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan. | 27,033 | 12,500 | 7446 | 11,278 | 13,700 | 18,289 | 34,044 | 7011 | 0.90 | 1.33 | | 0 |
| Jan. | 34,044 | 12,500 | 8246 | 12,490 | 4,650 | 12,375 | 33,929 | −114 | 1.00 | 2.66 | | 0 |
| Jan. | 33,929 | 12,500 | 7560 | 11,451 | 5,000 | 9,224 | 31,703 | −2226 | 0.92 | 1.84 | | 0 |
| Jan. | 31,703 | 12,500 | 7217 | 10,932 | 9,800 | 5,181 | 25,953 | −5750 | 0.87 | 0.53 | | 0 |
| Jan. | 25,953 | 12,500 | 7560 | 11,451 | 12,750 | 15,523 | 30,026 | 4072 | 0.92 | 1.22 | 8092 | 0 |
| Feb. | 30,026 | 12,500 | 7560 | 11,451 | 13,200 | 12,038 | 30,613 | 587 | 0.92 | 0.91 | | 0 |
| Feb. | 30,613 | 11,000 | 6281 | 9,514 | 11,050 | 9,690 | 30,790 | 176 | 0.86 | 0.88 | | 0 |
| Feb. | 30,790 | 12,500 | 7903 | 11,971 | 11,850 | 10,807 | 29,626 | −1163 | 0.96 | 0.91 | | 0 |
| Feb. | 29,626 | 12,500 | 6074 | 9,201 | 13,700 | 10,836 | 31,262 | 1635 | 0.74 | 0.79 | 1164 | 0 |
| Mar. | 31,262 | 12,500 | 7903 | 11,971 | 10,000 | 5,963 | 25,255 | −6007 | 0.96 | 0.60 | | 0 |
| Mar. | 25,255 | 12,500 | 8017 | 12,144 | 12,550 | 11,158 | 24,270 | −985 | 0.97 | 0.89 | | 0 |
| Mar. | 24,270 | 12,500 | 8703 | 13,182 | 12,650 | 10,448 | 21,537 | −2733 | 1.05 | 0.83 | | 0 |
| Mar. | 21,537 | 12,500 | 8931 | 13,528 | 12,900 | 11,764 | 19,773 | −1763 | 1.08 | 0.91 | 9725 | 0 |
| Apr. | 19,773 | 12,500 | 7674 | 11,624 | 14,450 | 12,181 | 20,331 | 557 | 0.93 | 0.84 | | 0 |
| Apr. | 20,331 | 12,500 | 7789 | 11,798 | 14,300 | 10,581 | 19,115 | −1216 | 0.94 | 0.74 | | 0 |
| Apr. | 19,115 | 12,500 | 8931 | 13,528 | 13,800 | 9,259 | 14,847 | −4268 | 1.08 | 0.67 | | 0 |
| Apr. | 14,847 | 11,000 | 6710 | 10,163 | 14,550 | 10,487 | 15,171 | 324 | 0.92 | 0.72 | | 0 |
| Apr. | 15,171 | 12,500 | 8246 | 12,490 | 15,300 | 13,541 | 16,222 | 1051 | 1.00 | 0.89 | 5484 | 5,000 |
| May | 16,222 | 12,500 | 8703 | 13,182 | 15,900 | 14,567 | 17,608 | 1385 | 1.05 | 0.92 | | 5,000 |
| May | 17,608 | 8,000 | 5478 | 8,297 | 10,050 | 9,012 | 18,323 | 715 | 1.04 | 0.90 | | 2,500 |
| May | 18,323 | 11,000 | 6977 | 10,568 | 12,600 | 8,706 | 16,462 | −1861 | 0.96 | 0.69 | | 0 |
| May | 16,462 | 12,500 | 8132 | 12,317 | 15,000 | 14,528 | 18,674 | 2211 | 0.99 | 0.97 | 2101 | 0 |
| June | 18,674 | 12,500 | 8246 | 12,490 | 14,700 | 14,979 | 21,163 | 2489 | 1.00 | 1.02 | | 2,500 |
| June | 21,163 | 12,500 | 7903 | 11,971 | 13,950 | 8,914 | 18,106 | −3056 | 0.96 | 0.64 | | 0 |
| June | 18,106 | 12,500 | 7789 | 11,798 | 15,400 | 9,039 | 15,348 | −2758 | 0.94 | 0.59 | | 0 |
| June | 15,348 | 12,500 | 7217 | 10,932 | 16,400 | 11,703 | 16,120 | 771 | 0.87 | 0.71 | 5815 | 0 |
| July | 16,120 | 12,500 | 7789 | 11,798 | 15,500 | 11,049 | 15,372 | −748 | 0.94 | 0.71 | | 5,000 |
| July | 15,372 | 12,500 | 7217 | 10,932 | 15,900 | 11,883 | 16,324 | 951 | 0.87 | 0.75 | | 2,500 |
| July | 16,324 | 12,500 | 9045 | 13,701 | 14,500 | 12,213 | 14,837 | −1487 | 1.10 | 0.84 | | 5,000 |
| July | 14,837 | 12,500 | 8703 | 13,182 | 15,850 | 9,900 | 11,555 | −3281 | 1.05 | 0.62 | | 2,500 |
| July | 11,555 | 12,500 | 9045 | 13,701 | 17,700 | 11,472 | 9,327 | −2228 | 1.10 | 0.65 | 4769 | 5,000 |
| Aug. | 9,327 | 12,500 | 7674 | 11,624 | 18,950 | 11,410 | 9,113 | −213 | 0.93 | 0.60 | | 12,500 |
| Aug. | 9,113 | 11,000 | 7565 | 11,459 | 18,050 | 13,413 | 11,067 | 1954 | 1.04 | 0.74 | | 20,000 |
| Aug. | 11,067 | 11,000 | 7298 | 11,054 | 16,300 | 11,674 | 11,687 | 620 | 1.00 | 0.72 | | 20,000 |
| Aug. | 11,687 | 12,500 | 8246 | 12,490 | 17,550 | 14,212 | 13,410 | 1722 | 1.00 | 0.81 | 2575 | 15,000 |
| Sept. | 13,410 | 10,500 | 7877 | 11,932 | 14,000 | 9,867 | 11,346 | −2064 | 1.14 | 0.70 | | 12,500 |
| Sept. | 11,346 | 12,500 | 8132 | 12,317 | 17,400 | 12,266 | 11,295 | −50 | 0.99 | 0.70 | | 10,000 |
| Sept. | 11,295 | 12,500 | 7217 | 10,932 | 17,150 | 15,333 | 15,696 | 4401 | 0.87 | 0.89 | | 12,500 |
| Sept. | 15,696 | 12,500 | 8360 | 12,663 | 16,800 | 8,962 | 11,995 | −3700 | 1.01 | 0.53 | 4401 | 12,500 |
| Oct. | 11,995 | 11,000 | 7672 | 11,621 | 15,800 | 11,161 | 11,536 | −459 | 1.06 | 0.71 | | 5,000 |
| Oct. | 11,536 | 11,000 | 7351 | 11,135 | 16,300 | 13,305 | 13,706 | 2170 | 1.01 | 0.82 | | 12,500 |
| Oct. | 13,706 | 12,500 | 7903 | 11,971 | 16,800 | 12,475 | 14,211 | 504 | 0.96 | 0.74 | | 12,500 |
| Oct. | 14,211 | 12,500 | 9045 | 13,701 | 17,150 | 13,159 | 13,669 | −541 | 1.10 | 0.77 | | 7,500 |
| Oct. | 13,669 | 12,500 | 7560 | 11,451 | 16,750 | 11,153 | 13,371 | −297 | 0.92 | 0.67 | 2675 | 7,500 |
| Nov. | 13,371 | 12,500 | 8703 | 13,182 | 17,450 | 18,865 | 19,055 | 5683 | 1.05 | 1.08 | | 7,500 |
| Nov. | 19,055 | 8,000 | 4889 | 7,406 | 9,700 | 13,271 | 24,920 | 5865 | 0.93 | 1.37 | | 10,000 |
| Nov. | 24,920 | 12,500 | 7446 | 11,278 | 12,800 | 14,131 | 27,773 | 2853 | 0.90 | 1.10 | | 0 |
| Nov. | 27,773 | 12,500 | 6875 | 10,413 | 13,900 | 15,887 | 33,248 | 5474 | 0.83 | 1.14 | 14,402 | 0 |
| Dec. | 33,248 | 12,500 | 8931 | 13,528 | 8,000 | 14,171 | 33,892 | 643 | 1.08 | 1.77 | | 0 |
| Dec. | 33,892 | 12,500 | 7560 | 11,451 | 5,900 | 8,152 | 30,594 | −3298 | 0.92 | 1.38 | | 0 |
| Dec. | 30,594 | 12,500 | 8017 | 12,144 | 12,350 | 6,714 | 25,164 | −5429 | 0.97 | 0.54 | | 0 |
| Dec. | 25,164 | 8,300 | 5355 | 8,111 | 9,200 | 11,573 | 28,626 | 3462 | 0.98 | 1.26 | 8728 | 0 |

**Table II. Simulation of Operations at the St. Regis Mill—Model No. 1, Yearly Operational Data**

| Year | Av. inventory cords | Maximum inventory Cords | Mo. | Minimum inventory Cords | Mo. | Total wood usage, cords | Av. daily prodn., tons | Maximum inventory range, cords | Standard devn. inventory | Standard devn. Wood orders | Av. predn., efficiency | Av. procurement efficiency | Total wood recd., cords | Av. week usage, cords | Total paper prodn., tons | Extra wood cost, dollars |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 21,064 | 36,211 | 11 | 8,143 | 7 | 618,522 | 1131 | 28,068 | 6483 | 3187 | 0.99 | 0.95 | 618,279 | 11,894 | 408,373 | 160,000 |
| 2 | 20,001 | 38,633 | 11 | 8,272 | 7 | 603,194 | 1103 | 30,360 | 7337 | 3751 | 0.97 | 0.97 | 608,088 | 11,599 | 398,253 | 180,000 |
| 3 | 20,440 | 34,724 | 11 | 2,508 | 8 | 615,175 | 1125 | 32,215 | 6850 | 3406 | 0.99 | 0.93 | 611,174 | 11,830 | 406,163 | 197,500 |
| 4 | 20,761 | 36,851 | 1 | 9,093 | 9 | 611,964 | 1119 | 27,757 | 6018 | 2885 | 0.98 | 0.93 | 610,846 | 11,768 | 404,043 | 107,500 |
| 5 | 20,174 | 34,044 | 1 | 9,112 | 8 | 606,899 | 1109 | 24,931 | 7638 | 3307 | 0.97 | 0.91 | 608,492 | 11,671 | 400,699 | 212,500 |
| 6 | 20,781 | 35,010 | 11 | 9,566 | 4 | 614,261 | 1123 | 25,444 | 5933 | 2915 | 0.98 | 0.94 | 601,774 | 11,812 | 405,560 | 85,000 |
| 7 | 20,932 | 36,178 | 12 | 8,815 | 10 | 621,504 | 1136 | 27,362 | 5196 | 2815 | 0.99 | 0.78 | 639,083 | 11,952 | 410,342 | 100,000 |
| 8 | 21,847 | 31,965 | 6 | 11,619 | 4 | 615,629 | 1125 | 20,346 | 5419 | 2090 | 0.98 | 0.88 | 609,415 | 11,839 | 406,463 | 80,000 |
| 9 | 20,859 | 32,406 | 12 | 6,071 | 10 | 625,563 | 1144 | 26,334 | 7397 | 3156 | 1.00 | 0.90 | 630,064 | 12,030 | 413,022 | 190,000 |
| 10 | 20,545 | 35,463 | 11 | 9,053 | 4 | 616,574 | 1127 | 26,409 | 7387 | 3324 | 0.98 | 0.91 | 610,790 | 11,857 | 407,087 | 205,000 |
| 11 | 20,547 | 33,286 | 12 | 8,746 | 9 | 612,748 | 1120 | 24,539 | 5913 | 2202 | 0.98 | 0.87 | 619,811 | 11,783 | 404,561 | 140,000 |
| 12 | 20,676 | 33,892 | 1 | 8,468 | 10 | 626,349 | 1145 | 25,424 | 6287 | 2869 | 1.00 | 0.92 | 622,144 | 12,045 | 413,541 | 155,000 |
| 13 | 20,323 | 43,600 | 1 | 8,250 | 8 | 619,991 | 1133 | 35,350 | 7131 | 3684 | 0.99 | 1.01 | 613,232 | 11,922 | 409,343 | 160,000 |
| 14 | 18,863 | 33,635 | 1 | 808 | 8 | 623,908 | 1141 | 32,826 | 7180 | 3443 | 1.00 | 0.87 | 631,232 | 11,998 | 411,929 | 297,500 |
| 15 | 20,878 | 38,363 | 12 | 7,760 | 7 | 600,840 | 1098 | 30,603 | 7666 | 3890 | 0.96 | 0.95 | 597,433 | 11,554 | 396,699 | 195,000 |
| 16 | 20,514 | 32,668 | 1 | 6,703 | 9 | 621,063 | 1135 | 25,964 | 6532 | 2716 | 0.99 | 0.87 | 624,767 | 11,943 | 410,051 | 205,000 |
| 17 | 21,512 | 39,516 | 1 | 13,256 | 4 | 601,268 | 1099 | 26,259 | 5945 | 2965 | 0.96 | 0.94 | 601,413 | 11,562 | 396,981 | 67,500 |
| 18 | 20,180 | 35,265 | 1 | 7,885 | 8 | 611,227 | 1117 | 27,379 | 6524 | 3144 | 0.98 | 0.91 | 611,548 | 11,754 | 403,557 | 185,000 |
| 19 | 20,532 | 32,990 | 1 | 9,902 | 10 | 620,450 | 1134 | 23,088 | 6739 | 2762 | 0.99 | 0.89 | 619,075 | 11,931 | 409,646 | 175,000 |
| 20 | 21,412 | 34,814 | 12 | 10,479 | 7 | 611,943 | 1119 | 24,334 | 6684 | 3009 | 0.99 | 0.76 | 616,339 | 11,768 | 404,029 | 142,500 |
| 21 | 20,442 | 38,101 | 12 | 6,864 | 9 | 607,413 | 1110 | 31,236 | 7661 | 4068 | 0.97 | 0.91 | 596,506 | 11,681 | 401,039 | 240,000 |
| 22 | 20,203 | 33,807 | 11 | 5,604 | 10 | 619,753 | 1133 | 28,203 | 6816 | 3415 | 1.00 | 0.90 | 622,245 | 11,918 | 409,186 | 240,000 |
| 23 | 19,227 | 34,894 | 1 | 9,815 | 7 | 622,739 | 1138 | 25,078 | 6787 | 2922 | 1.00 | 0.91 | 628,831 | 11,975 | 411,157 | 212,500 |
| 24 | 21,102 | 34,798 | 12 | 5,602 | 8 | 613,733 | 1122 | 29,195 | 6150 | 3030 | 0.98 | 0.90 | 605,420 | 11,802 | 405,211 | 130,000 |
| 25 | 20,141 | 36,364 | 12 | 8,924 | 8 | 614,011 | 1122 | 27,439 | 6542 | 3402 | 0.99 | 0.97 | 612,890 | 11,807 | 405,395 | 167,500 |
| 26 | 19,767 | 34,899 | 1 | 5,603 | 8 | 616,837 | 1128 | 29,295 | 6670 | 3237 | 0.99 | 0.90 | 627,466 | 11,862 | 407,261 | 222,500 |
| 27 | 20,761 | 32,969 | 1 | 11,617 | 9 | 615,303 | 1125 | 21,351 | 5527 | 2503 | 0.99 | 0.90 | 613,955 | 11,832 | 406,248 | 82,500 |
| 28 | 20,349 | 38,782 | 12 | 10,244 | 7 | 605,357 | 1107 | 28,538 | 6363 | 3602 | 0.96 | 0.99 | 596,204 | 11,641 | 399,681 | 107,500 |
| 29 | 21,280 | 32,048 | 1 | 10,510 | 10 | 620,732 | 1135 | 21,538 | 5220 | 2123 | 0.99 | 0.91 | 630,806 | 11,937 | 409,832 | 87,500 |
| 30 | 22,066 | 34,893 | 1 | 7,941 | 10 | 609,152 | 1114 | 26,951 | 6686 | 3296 | 0.97 | 0.93 | 606,118 | 11,714 | 402,187 | 160,000 |
| 31 | 20,058 | 40,063 | 1 | 9,922 | 7 | 603,834 | 1104 | 30,141 | 6863 | 3541 | 0.96 | 0.89 | 599,907 | 11,612 | 398,675 | 167,500 |
| 32 | 21,066 | 35,953 | 12 | 10,995 | 7 | 599,995 | 1097 | 24,958 | 6231 | 3459 | 0.97 | 0.96 | 597,776 | 11,538 | 396,141 | 90,000 |
| 33 | 19,860 | 37,217 | 12 | 8,139 | 4 | 601,604 | 1099 | 29,077 | 6014 | 3041 | 0.96 | 0.64 | 613,704 | 11,557 | 396,807 | 145,000 |
| 34 | 22,301 | 33,138 | 3 | 8,074 | 7 | 602,687 | 1102 | 25,064 | 5951 | 3005 | 0.97 | 0.90 | 598,182 | 11,590 | 397,918 | 97,500 |
| 35 | 21,815 | 36,778 | 12 | 3,651 | 7 | 618,817 | 1131 | 33,127 | 7308 | 3703 | 0.99 | 0.81 | 619,533 | 11,900 | 408,568 | 195,000 |
| 36 | 19,594 | 29,514 | 12 | 8,061 | 7 | 626,460 | 1145 | 21,453 | 6091 | 2413 | 1.00 | 0.85 | 621,199 | 12,047 | 413,614 | 215,000 |
| 37 | 20,523 | 35,436 | 1 | 8,850 | 7 | 616,262 | 1127 | 26,585 | 6600 | 3041 | 0.99 | 0.92 | 617,206 | 11,851 | 406,881 | 185,000 |
| 38 | 20,621 | 39,659 | 12 | 7,521 | 9 | 607,640 | 1111 | 32,137 | 7054 | 4114 | 0.98 | 1.08 | 610,868 | 11,685 | 401,188 | 152,500 |
| 39 | 22,393 | 38,709 | 11 | 11,370 | 10 | 615,249 | 1125 | 27,339 | 5215 | 2543 | 0.99 | 0.96 | 607,535 | 11,831 | 406,212 | 40,000 |
| 40 | 21,322 | 33,007 | 1 | 12,050 | 10 | 619,652 | 1133 | 20,956 | 5744 | 2375 | 0.98 | 0.91 | 626,078 | 11,916 | 409,119 | 95,000 |
| 41 | 21,347 | 33,478 | 12 | 12,553 | 10 | 614,297 | 1123 | 20,925 | 5970 | 2712 | 0.98 | 0.90 | 610,454 | 11,813 | 405,584 | 92,500 |
| 42 | 19,929 | 31,961 | 12 | 6,549 | 7 | 620,536 | 1134 | 25,411 | 5145 | 2238 | 0.99 | 0.87 | 627,101 | 11,933 | 409,703 | 127,500 |
| 43 | 21,768 | 34,167 | 1 | 11,091 | 10 | 627,622 | 1147 | 23,076 | 4971 | 2337 | 1.00 | 0.93 | 625,861 | 12,069 | 414,381 | 55,000 |
| 44 | 19,864 | 41,491 | 12 | 5,107 | 7 | 614,352 | 1123 | 36,383 | 7787 | 4012 | 0.98 | 0.94 | 610,386 | 11,814 | 405,620 | 237,500 |
| 45 | 20,068 | 37,206 | 12 | 8,133 | 7 | 612,580 | 1120 | 29,073 | 6764 | 3276 | 0.99 | 0.75 | 623,568 | 11,780 | 404,450 | 160,000 |
| 46 | 20,654 | 37,119 | 12 | 1,894 | 10 | 609,656 | 1115 | 35,224 | 7031 | 3923 | 0.97 | 0.89 | 598,218 | 11,724 | 402,519 | 215,000 |
| 47 | 17,976 | 29,532 | 12 | 8,404 | 9 | 630,126 | 1152 | 21,127 | 5060 | 2329 | 1.00 | 0.83 | 633,890 | 12,117 | 416,035 | 220,000 |
| 48 | 21,564 | 40,800 | 12 | 10,328 | 8 | 599,404 | 1096 | 30,472 | 6540 | 3202 | 0.96 | 0.94 | 591,090 | 11,527 | 395,751 | 97,500 |
| 49 | 20,216 | 34,061 | 1 | 9,435 | 4 | 593,001 | 1084 | 24,626 | 5831 | 2694 | 0.96 | 0.88 | 599,463 | 11,403 | 391,523 | 145,000 |
| 50 | 19,681 | 34,782 | 1 | 8,587 | 10 | 611,035 | 1117 | 26,194 | 6779 | 3177 | 0.98 | 0.86 | 607,097 | 11,750 | 403,430 | 202,500 |

Fig. 4 is considered representative of the mill being studied during periods of steady production at near capacity levels. Actual usage values may be obtained by sampling function No. 1-J at random. In this manner uncertainty will be introduced as is present in real life, when normal production is predicted. Alternate functions may also be constructed if it is desired to determine the relative effect of higher production levels or increased variability as might be encountered with complicated production schedules. Alternate functions can also be constructed to simulate higher production levels and/or increased variability of wood consumption which might result from production scheduling rules or other factors.

## INVENTORY CHANGES

The amounts of wood used and received in any week determine the change in inventory for that week. It has been shown that wood usage data can be developed for successive weeks of a year from function No. 1-J and equation (12):

$$U_{an} = P_{Un} + E_{pn} \quad (P_{Un} < 12{,}500)$$
$$U_{an} \rightarrow f(1 - J) \quad (P_{Un} - 12{,}500) \qquad (12)$$

It has also been shown that data on total wood receipts over a year can be obtained by evaluating equation (11):

$$R_{Tn} = (P_{Un} + I_{an} + S_{an})P_{rn} + R_{dn} \qquad (11)$$

Change in inventory, $\Delta I_n$, is the difference between receipts and usage. It is also the difference in the size of the inventory from the beginning to the end of a week. These statements may be expressed as:

$$\Delta I_n = R_{Tn} - U_{an} = I_{En} - I_{Bn} \qquad (13)$$

where

$I_{Bn}$ = size of beginning inventory for any particular week in cords.

$I_{En}$ = size of ending inventory for any particular week in cords.

Equation (13) may be rewritten in the equivalent form:

$$I_{En} = I_{Bn} + \Delta I_n \qquad (14)$$

or

$$I_{En} = I_{Bn} + R_{Tn} - U_{an} \qquad (15)$$

The ending inventory for a particular week becomes the beginning inventory for the next succeeding week.

This may be expressed as:

$$I_{En} = I_{B(n+1)} \quad (16)$$

or

$$I_{Bn} = I_{E(n-1)} \quad (17)$$

From this it follows that:

$$I_{B02} = I_{E01} \quad (18)$$
$$I_{B03} = I_{E02} \quad (19)$$
$$\vdots$$
$$I_{B52} = I_{E51} \quad (20)$$

The most significant elements of the model have been presented in foregoing discussions. They are summarized by the schematic diagram in Fig. 5. By following the computational procedures outlined, operational data simulating procurement and production operations can be obtained for as many weeks or years as desired.

## PRELIMINARY TESTING OF MODEL

A record of one year's operation was obtained from the model by manual computation. Random selection of values from probability distributions were obtained by using a published series of random numbers.* Some refinements were made in the model after the first run was reviewed with production and procurement personnel. A second test run was then made and approved prior to beginning more extensive calculations.

To prepare the model for a computer, a means to generate random numbers was required and a method of separating appropriate function values from prob-

* "A Million Random Digits," The Rand Corp., Free Press.

**Table III. Simulation of Operations at the St. Regis Mill, Extended Period Analysis Statement**

| No. of years | Av. inventory range | Standard devn. inventory range | Maximum inventory* Range | Maximum inventory* Year | Minimum inventory* Range | Minimum inventory* Year | Chi squared inventory* range | Av. extra wood cost | Av. range of inventory—100 cords Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Model no. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 50 | 27,143 | 3936 | 36,383 | 44 | 20,345 | 8 | 11 | 156,500 | 81 | 79 | 50 | 64 | 55 | 49 | 77 | 65 | 71 | 77 | 128 | 85 | 1 |
| 60 | 26,872 | 4341 | 41,488 | 10 | 19,212 | 8 | 22 | 152,833 | 82 | 77 | 51 | 64 | 54 | 49 | 77 | 62 | 66 | 77 | 125 | 83 | |
| 70 | 26,905 | 4237 | 32,764 | 4 | 21,797 | 7 | 33 | 154,179 | 80 | 79 | 52 | 63 | 51 | 50 | 79 | 63 | 67 | 78 | 123 | 80 | |
| 80 | 26,949 | 4133 | 32,477 | 6 | 21,658 | 4 | 48 | 155,063 | 81 | 79 | 51 | 62 | 51 | 49 | 79 | 65 | 67 | 76 | 125 | 78 | |
| 90 | 26,959 | 4037 | 33,489 | 2 | 22,445 | 9 | 63 | 153,917 | 82 | 80 | 51 | 63 | 51 | 51 | 78 | 65 | 66 | 76 | 124 | 79 | |
| 100 | 27,032 | 4091 | 37,408 | 2 | 22,393 | 2 | 78 | 152,500 | 84 | 80 | 51 | 62 | 52 | 52 | 77 | 64 | 65 | 76 | 122 | 79 | |
| 50 | 24,625 | 3629 | 32,883 | 44 | 17,888 | 29 | 13 | 177,600 | 66 | 74 | 50 | 67 | 58 | 50 | 77 | 71 | 74 | 81 | 122 | 73 | 2 |
| 60 | 24,383 | 4061 | 37,664 | 10 | 16,912 | 29 | 29 | 174,583 | 66 | 73 | 51 | 67 | 56 | 50 | 77 | 67 | 70 | 82 | 120 | 70 | |
| 70 | 24,366 | 4015 | 29,904 | 4 | 18,778 | 7 | 51 | 176,357 | 65 | 75 | 53 | 66 | 54 | 50 | 79 | 67 | 71 | 83 | 117 | 67 | |
| 80 | 24,380 | 3867 | 30,168 | 6 | 21,209 | 2 | 71 | 177,625 | 65 | 75 | 52 | 64 | 54 | 50 | 79 | 70 | 70 | 82 | 118 | 65 | |
| 90 | 24,360 | 3779 | 30,418 | 2 | 19,299 | 9 | 86 | 176,667 | 64 | 76 | 52 | 65 | 54 | 51 | 79 | 70 | 70 | 82 | 117 | 65 | |
| 100 | 24,440 | 3904 | 34,467 | 2 | 18,756 | 2 | 101 | 174,500 | 66 | 77 | 51 | 65 | 55 | 52 | 77 | 69 | 68 | 82 | 116 | 65 | |
| 110 | 24,460 | 3764 | 28,380 | 7 | 22,372 | 6 | 120 | 174,250 | 67 | 77 | 51 | 63 | 55 | 52 | 78 | 69 | 67 | 82 | 116 | 65 | |
| 50 | 25,811 | 3747 | 34,779 | 35 | 18,632 | 29 | 10 | 208,600 | 70 | 79 | 53 | 73 | 64 | 54 | 84 | 79 | 77 | 89 | 128 | 78 | 3 |
| 60 | 25,617 | 4212 | 40,256 | 10 | 18,676 | 29 | 19 | 205,458 | 70 | 78 | 54 | 73 | 62 | 53 | 84 | 74 | 73 | 89 | 127 | 74 | |
| 70 | 25,599 | 4186 | 30,838 | 4 | 20,038 | 6 | 35 | 207,429 | 68 | 81 | 56 | 71 | 59 | 54 | 86 | 73 | 74 | 90 | 124 | 71 | |
| 80 | 25,627 | 4055 | 32,596 | 6 | 22,193 | 2 | 50 | 208,656 | 69 | 80 | 56 | 70 | 59 | 53 | 86 | 76 | 74 | 89 | 125 | 69 | |
| 90 | 25,639 | 3963 | 32,630 | 2 | 21,211 | 9 | 62 | 207,694 | 69 | 81 | 56 | 71 | 59 | 54 | 85 | 76 | 74 | 89 | 124 | 69 | |
| 50 | 28,590 | 4004 | 38,776 | 44 | 21,544 | 8 | 7 | 185,800 | 86 | 85 | 53 | 70 | 60 | 53 | 82 | 70 | 75 | 83 | 135 | 90 | 4 |
| 60 | 28,324 | 4345 | 41,736 | 10 | 20,395 | 8 | 14 | 182,125 | 87 | 84 | 53 | 70 | 58 | 53 | 83 | 67 | 71 | 83 | 133 | 86 | |
| 70 | 28,322 | 4292 | 34,341 | 4 | 22,795 | 6 | 26 | 183,107 | 85 | 85 | 55 | 68 | 55 | 53 | 85 | 67 | 71 | 84 | 130 | 84 | |
| 80 | 28,366 | 4176 | 34,440 | 6 | 23,828 | 4 | 40 | 184,000 | 85 | 85 | 54 | 67 | 55 | 52 | 84 | 70 | 71 | 83 | 132 | 83 | |
| 90 | 28,368 | 4094 | 35,006 | 2 | 23,762 | 9 | 58 | 182,806 | 86 | 86 | 54 | 67 | 56 | 54 | 84 | 70 | 70 | 82 | 131 | 83 | |
| 100 | 28,424 | 4180 | 39,627 | 2 | 23,561 | 2 | 79 | 181,425 | 88 | 87 | 53 | 67 | 57 | 55 | 82 | 69 | 69 | 82 | 129 | 83 | |
| 50 | 19,047 | 3617 | 26,741 | 44 | 12,562 | 47 | 10 | 14,150 | 66 | 54 | 38 | 42 | 35 | 32 | 47 | 40 | 39 | 52 | 66 | 62 | 5 |
| 60 | 19,054 | 4150 | 35,237 | 60 | 12,773 | 58 | 20 | 13,792 | 65 | 53 | 37 | 43 | 34 | 35 | 47 | 39 | 37 | 52 | 64 | 61 | |
| 70 | 19,025 | 4122 | 23,133 | 64 | 12,288 | 67 | 38 | 14,000 | 62 | 53 | 39 | 43 | 33 | 36 | 47 | 39 | 37 | 51 | 63 | 60 | |
| 80 | 18,997 | 4056 | 25,110 | 76 | 13,037 | 74 | 54 | 14,188 | 63 | 52 | 37 | 43 | 32 | 35 | 48 | 39 | 38 | 50 | 64 | 56 | |
| 90 | 18,911 | 4106 | 29,975 | 82 | 12,795 | 83 | 67 | 14,083 | 61 | 53 | 37 | 43 | 32 | 36 | 48 | 39 | 37 | 49 | 64 | 57 | |
| 100 | 18,977 | 4183 | 28,489 | 93 | 13,239 | 92 | 84 | 13,925 | 61 | 54 | 36 | 43 | 33 | 36 | 47 | 39 | 37 | 49 | 62 | 59 | |
| 50 | 17,111 | 3787 | 25,999 | 44 | 11,521 | 40 | 12 | 20,250 | 50 | 48 | 34 | 41 | 35 | 32 | 45 | 43 | 40 | 53 | 64 | 58 | 6 |
| 60 | 17,021 | 4172 | 31,437 | 60 | 10,742 | 58 | 23 | 19,625 | 51 | 47 | 36 | 42 | 34 | 33 | 45 | 42 | 38 | 53 | 61 | 56 | |
| 70 | 16,939 | 4110 | 21,166 | 64 | 10,073 | 67 | 34 | 19,714 | 49 | 46 | 37 | 42 | 33 | 33 | 45 | 41 | 38 | 52 | 61 | 53 | |
| 80 | 16,889 | 4038 | 22,539 | 76 | 10,840 | 74 | 46 | 20,000 | 50 | 46 | 36 | 41 | 33 | 33 | 46 | 42 | 38 | 51 | 61 | 51 | |
| 90 | 16,863 | 4027 | 27,537 | 82 | 13,407 | 83 | 54 | 19,667 | 49 | 47 | 36 | 42 | 32 | 35 | 46 | 41 | 37 | 50 | 61 | 50 | |
| 100 | 17,001 | 4117 | 26,173 | 91 | 11,802 | 92 | 66 | 19,850 | 49 | 47 | 35 | 42 | 33 | 35 | 46 | 42 | 37 | 50 | 59 | 52 | |
| 110 | 17,096 | 4041 | 22,935 | 107 | 13,218 | 108 | 79 | 19,545 | 50 | 47 | 34 | 41 | 33 | 36 | 46 | 42 | 36 | 51 | 60 | 51 | |
| 50 | 18,128 | 4064 | 26,565 | 44 | 12,098 | 40 | 14 | 27,250 | 53 | 50 | 37 | 44 | 37 | 33 | 47 | 45 | 43 | 57 | 68 | 60 | |
| 60 | 17,995 | 4441 | 32,804 | 60 | 11,569 | 58 | 27 | 26,333 | 53 | 48 | 37 | 45 | 37 | 34 | 48 | 44 | 40 | 57 | 65 | 58 | |
| 70 | 17,924 | 4378 | 22,740 | 64 | 10,619 | 67 | 40 | 26,464 | 52 | 48 | 38 | 45 | 36 | 35 | 48 | 43 | 41 | 56 | 65 | 56 | |
| 80 | 17,855 | 4310 | 23,974 | 76 | 10,945 | 74 | 53 | 26,813 | 52 | 48 | 37 | 44 | 35 | 35 | 49 | 44 | 41 | 54 | 65 | 54 | |
| 90 | 17,832 | 4343 | 29,991 | 82 | 14,156 | 86 | 63 | 26,250 | 52 | 49 | 37 | 44 | 35 | 36 | 49 | 44 | 40 | 53 | 64 | 53 | |
| 100 | 17,993 | 4455 | 28,634 | 91 | 12,354 | 92 | 76 | 26,400 | 52 | 50 | 36 | 44 | 35 | 37 | 48 | 44 | 39 | 53 | 63 | 54 | |
| 110 | 18,087 | 4386 | 24,439 | 105 | 13,570 | 108 | 90 | 26,182 | 53 | 49 | 36 | 43 | 35 | 37 | 49 | 44 | 38 | 54 | 64 | 54 | |
| 50 | 20,038 | 3751 | 28,222 | 44 | 13,523 | 29 | 13 | 19,550 | 71 | 58 | 38 | 44 | 37 | 33 | 49 | 44 | 42 | 56 | 70 | 66 | |
| 60 | 20,026 | 4385 | 38,011 | 60 | 13,359 | 58 | 27 | 18,667 | 69 | 57 | 37 | 45 | 36 | 35 | 49 | 42 | 39 | 55 | 68 | 65 | |
| 70 | 19,901 | 4312 | 24,779 | 64 | 12,993 | 67 | 43 | 18,714 | 67 | 57 | 39 | 45 | 34 | 36 | 49 | 41 | 40 | 54 | 67 | 63 | |
| 80 | 19,910 | 4242 | 26,763 | 76 | 13,851 | 74 | 59 | 19,219 | 67 | 55 | 38 | 44 | 34 | 35 | 50 | 42 | 40 | 53 | 67 | 59 | |
| 90 | 19,831 | 4314 | 32,228 | 82 | 14,591 | 83 | 72 | 18,917 | 65 | 57 | 38 | 45 | 33 | 36 | 50 | 42 | 39 | 52 | 67 | 60 | |
| 100 | 19,967 | 4406 | 29,712 | 93 | 14,114 | 92 | 88 | 19,075 | 65 | 59 | 37 | 45 | 34 | 37 | 49 | 42 | 38 | 52 | 65 | 62 | |
| 110 | 20,025 | 4339 | 26,945 | 105 | 15,668 | 104 | 103 | 19,045 | 65 | 58 | 36 | 43 | 34 | 38 | 49 | 42 | 38 | 52 | 66 | 62 | |
| 120 | 19,900 | 4338 | 26,867 | 120 | 13,671 | 115 | 119 | 19,188 | 65 | 58 | 37 | 44 | 35 | 38 | 49 | 41 | 37 | 52 | 65 | 62 | |
| 130 | 19,905 | 4241 | 23,409 | 130 | 13,818 | 124 | 136 | 19,942 | 65 | 57 | 36 | 44 | 34 | 37 | 50 | 43 | 38 | 51 | 66 | 62 | |
| 140 | 19,918 | 4218 | 26,579 | 137 | 15,343 | 139 | 157 | 19,714 | 65 | 57 | 37 | 45 | 35 | 38 | 49 | 44 | 37 | 50 | 66 | 63 | |
| 150 | 19,897 | 4130 | 26,346 | 147 | 17,385 | 146 | 178 | 19,533 | 68 | 57 | 36 | 44 | 34 | 38 | 49 | 44 | 37 | 50 | 65 | 62 | |
| 160 | 19,866 | 4061 | 22,682 | 151 | 13,689 | 158 | 199 | 19,406 | 67 | 57 | 36 | 44 | 35 | 38 | 49 | 43 | 37 | 50 | 67 | 61 | |
| 170 | 19,959 | 4049 | 28,572 | 162 | 15,353 | 168 | 223 | 19,809 | 68 | 57 | 36 | 44 | 35 | 38 | 50 | 43 | 36 | 50 | 67 | 60 | |
| 180 | 19,886 | 4119 | 30,061 | 177 | 11,005 | 172 | 246 | 20,222 | 67 | 56 | 36 | 44 | 35 | 38 | 50 | 43 | 37 | 50 | 68 | 60 | |
| 190 | 19,881 | 4042 | 24,769 | 190 | 16,323 | 187 | 269 | 19,855 | 68 | 57 | 36 | 44 | 34 | 37 | 49 | 43 | 37 | 50 | 69 | 61 | |
| 200 | 19,850 | 3990 | 34,781 | 192 | 14,710 | 200 | 288 | 20,138 | 68 | 58 | 36 | 44 | 34 | 37 | 49 | 43 | 37 | 50 | 69 | 61 | |
| 210 | 19,749 | 3999 | 23,243 | 201 | 10,749 | 210 | 309 | 19,679 | 68 | 57 | 36 | 44 | 34 | 37 | 49 | 43 | 37 | 50 | 69 | 61 | |
| 220 | 19,812 | 3983 | 27,538 | 215 | 17,202 | 219 | 332 | 19,670 | 67 | 57 | 36 | 44 | 33 | 38 | 49 | 43 | 36 | 50 | 70 | 62 | |
| 230 | 19,807 | 3994 | 25,902 | 228 | 11,762 | 222 | 354 | 19,750 | 67 | 56 | 36 | 44 | 33 | 38 | 49 | 43 | 37 | 51 | 70 | 62 | |
| 240 | 19,780 | 3950 | 23,446 | 234 | 15,499 | 237 | 376 | 19,406 | 67 | 56 | 36 | 43 | 34 | 38 | 49 | 43 | 36 | 51 | 69 | 61 | |
| 250 | 19,774 | 3943 | 26,279 | 245 | 14,162 | 242 | 400 | 19,770 | 67 | 55 | 37 | 43 | 33 | 39 | 49 | 43 | 37 | 51 | 69 | 60 | |
| 260 | 19,728 | 3910 | 23,642 | 253 | 13,743 | 259 | 426 | 19,538 | 67 | 56 | 37 | 43 | 34 | 38 | 49 | 43 | 37 | 51 | 69 | 59 | |
| 270 | 19,688 | 3902 | 23,597 | 266 | 13,177 | 263 | 451 | 19,065 | 67 | 57 | 37 | 43 | 34 | 39 | 49 | 43 | 37 | 50 | 69 | 60 | |
| 280 | 19,759 | 3880 | 26,413 | 274 | 18,155 | 271 | 477 | 19,045 | 67 | 58 | 37 | 44 | 34 | 39 | 49 | 42 | 36 | 50 | 70 | 59 | |
| 290 | 19,806 | 3944 | 32,001 | 285 | 15,716 | 286 | 506 | 19,336 | 67 | 58 | 36 | 44 | 35 | 39 | 49 | 42 | 37 | 51 | 70 | 60 | |
| 300 | 19,773 | 3942 | 26,060 | 294 | 14,295 | 300 | 535 | 19,517 | 67 | 58 | 36 | 44 | 34 | 39 | 51 | 42 | 37 | 51 | 69 | 59 | |
| 310 | 19,759 | 3893 | 24,295 | 303 | 17,213 | 305 | 566 | 19,508 | 66 | 58 | 36 | 44 | 34 | 39 | 51 | 42 | 37 | 51 | 69 | 59 | |

*An error in the computer program, detected too late for correction, makes all reported values of these parameters in Table III incorrect.

ability distributions. The Taussky-Todd method of producing random numbers was used. Basically it is a multiplicative process wherein the middle three significant decimal digits of the product $1.0 \times 5^{15}$ becomes the first random number. The entire product is then multiplied by $5^{15}$ and the middle three significant digits become the second random number. This process is repeated indefinitely. The method will cycle after $2^{33}$ numbers are produced.

All probability functions were reduced to table form. Each value of the function was identified with one or more numbers between 0 and 1000, in accordance with the shape of the particular distribution curve. In this way, each random number between 0 and 1000 has a corresponding function value which is considered to be selected at random from the population of values available.

An optical device known as a Lacey-Luci† was used to facilitate the reduction of original probability curves to table form. In most cases, the final shape of the curves was arrived at by successive steps of approximation, consultation, and refinement using reference data and the judgment of experienced respondents. The original curve was then enlarged on the Lacey-Luci until a specified area under the curve was obtained which would accommodate a fixed grid size. On this basis, probability curves could be compared directly, and the area under each curve was known to contain 1000 units of uniform size. Moreover with the "table-lookup" system it was not necessary to determine the equation of the curve for use in the computer, thereby facilitating the introduction of alternate input functions, particularly those with irregular shapes.

## FORMAT FOR DATA FROM MATHEMATICAL MODEL

To aid in the interpretation of data obtained from the mathematical model, the values of certain parameters were recorded and listed on a weekly basis (Table I).

The analysis of inventory variations and risk, however, required the accumulation of many years experience with the model. For this phase of the analysis it was more valuable to summarize operating data on a yearly basis. Parameters were selected and the results are given in Table II.

To further aid in the analysis of the data obtained from the mathematical model, weekly and yearly information were summarized in an extended period statement.—Values of the factors shown in Table III were selected as being significant for such a report.

## COMPUTER SIMULATION

The mathematical model was programmed for an IBM 704 digital comupter.

Approximately 120 man-hours time was required to prepare a finished program of the model for the computer. Computer time of 4.25 hr. were spent on compiling and testing program. Computer time of 4.47 hr were necessary to gather 1036 years of operational data from the model. To print all the data in final form 16.5 hr. of off-line printing equipment was required.

Eight variations of the general mathematical model, corresponding to changes in inventory policy, production level, and procurement procedure, were run on the computer. In each case, mill operations were repeated many times in order to observe the range of values of inventory level and other characteristics of plant performance. Operational data were presented in weekly, yearly, and extended period reports.

† Model G by Merritt Lacey Corp., Newark, N. J.

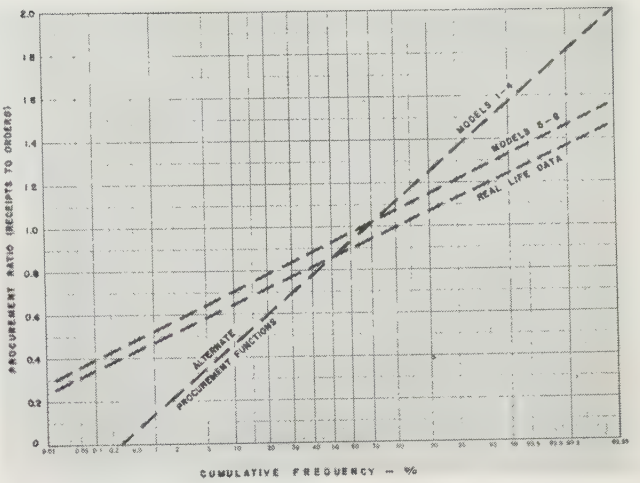


*Fig. 6. Cumulative frequency characteristics of procurement ratio; September–April*

## ANALYSIS OF RESULTS

The practical value of the Mathematical Model depends to a great extent on the accuracy with which the model reproduces real life before changes in the system are introduced. Accordingly, weekly and yearly operational data from the computer were examined carefully and compared with available real life data from the mill under study.

Particular attention was given to the variability of procurement ratio, since this factor was the most difficult to specify initially. Actual values of procurement ratio experienced for the mill under study were compared with operational data from the model. These data are shown graphically in Fig. 6.

The minimum inventory level was used as a criterion for evaluating the risk of running out of pulpwood. The frequency characteristics of the minimum inventory level are summarized in Table IV. These data were then plotted in terms of cumulative probability and extrapolated to zero inventory level in order to evaluate

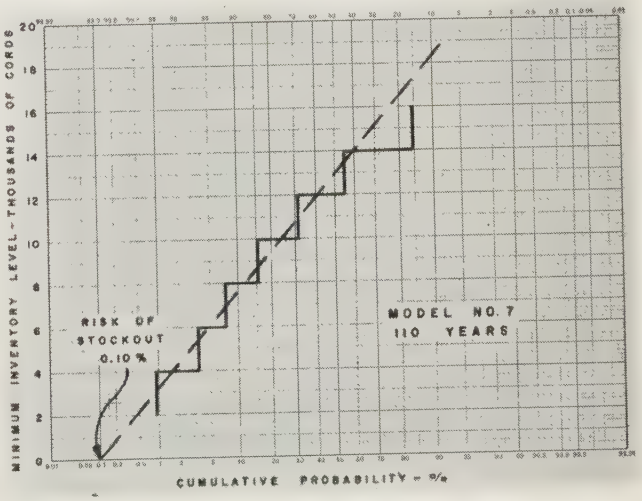


*Fig. 7. Cumulative probability plot of minimum inventory level for model no. 7*

Table IV. Frequency Characteristics of Minimum Inventory Level for Each of Eight Models Over Extended Periods of Operation

| Minimum inventory level | Frequency of occurrence in years | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 0– 1,999 | 3 | 4 | 7 | 7 | ... | ... | ... | ... |
| 2,000– 3,999 | 8 | 8 | 9 | 7 | ... | ... | 1 | ... |
| 4,000– 5,999 | 7 | 14 | 15 | 13 | ... | 2 | 3 | 1 |
| 6,000– 7,999 | 16 | 35 | 31 | 29 | 3 | 2 | 4 | 3 |
| 8,000– 9,999 | 36 | 37 | 23 | 26 | 1 | 8 | 9 | 4 |
| 10,000–11,999 | 24 | 11 | 5 | 15 | 9 | 18 | 18 | 14 |
| 12,000–13,999 | 5 | 1 | .. | 3 | 17 | 17 | 26 | 15 |
| 14,000–15,999 | 1 | ... | .. | ... | 25 | 41 | 32 | 29 |
| 16,000–17,999 | ... | ... | .. | ... | 29 | 22 | 17 | 29 |
| 18,000–20,000 | ... | ... | .. | ... | 22 | ... | ... | 15 |
| Number of years considered | 100 | 110 | 90 | 100 | 106 | 110 | 110 | 110 |

the chances of stockout. The method is shown graphically in Fig. 7.

Comparative operational data from the models are summarized in Table V.

In this report, the risk of stockout is synonymous with the "chances of requiring emergency procurement measures to prevent the mill from running out of pulpwood." Emergency measures could be effected in various ways, such as obtaining wood from cooperative mills nearby, planning a shutdown, or increasing cuttings from company lands near the mill. In any case, higher than normal costs would be experienced until normal procurement operations could be resumed.

Table V. Comparative Operational Data

| | Alternate procurement functions | | | | Present procurement functions | | | |
|---|---|---|---|---|---|---|---|---|
| | Low production | | High production | | Low production | | High production | |
| Inventory policy → | X | Y | X | Y | X | Y | X | Y |
| Model no. → | 1 | 2 | 4 | 3 | 5 | 6 | 8 | 7 |
| Average wood usage, cords | 611,974 | 612,974 | 656,539 | 656,593 | 612,974 | 613,974 | 656,539 | 659,539 |
| Average inventory level cords | 20,625 | 19,176 | 20,297 | 18,943 | 24,085 | 21,769 | 23,819 | 21,379 |
| Average maximum inventory range, cords | 27,032 | 24,440 | 28,424 | 25,639 | 18,977 | 17,001 | 19,967 | 17,993 |
| Risk of stockout | 2:100 | 2:100 | 3:100 | 4:100 | 1:10,000 | 1:20,000 | 1:50,000 | 1:10,000 |
| Probability of stockout, % | 2 | 2 | 3 | 4 | 0.01 | 0.05 | 0.02 | 0.10 |
| No. of years considered | 100 | 110 | 100 | 90 | 106 | 110 | 110 | 110 |

An analysis of the computer data shows that the minimum inventory level will most likely occur during the summer months. This characteristic is summarized in Table VI.

Table VI. Frequency of Occurrence of Minimum Inventory Level During Certain Months of the Year

| Model no. → | Frequency of occurrence in years | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Jan. | 0 | 0 | 0 | 0 | 2 | 1 | 1 | 2 |
| Feb. | 1 | 2 | 2 | 1 | 3 | 3 | | 3 |
| Mar. | 0 | 1 | 1 | 0 | 2 | 2 | 2 | 2 |
| Apr. | 8 | 9 | 9 | 10 | 9 | 10 | 10 | 10 |
| May | 1 | 1 | 0 | 1 | 5 | 7 | 7 | 6 |
| June | 3 | 4 | 4 | 3 | 4 | 6 | 4 | 4 |
| July | 28 | 28 | 25 | 31 | 19 | 25 | 27 | 22 |
| Aug. | 18 | 18 | 16 | 17 | 14 | 14 | 11 | 15 |
| Sept. | 14 | 13 | 10 | 12 | 17 | 13 | 13 | 13 |
| Oct. | 27 | 24 | 23 | 25 | 23 | 17 | 21 | 21 |
| Nov. | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 |
| Dec. | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| No. of years considered | 100 | 100 | 90 | 100 | 100 | 100 | 100 | 100 |

Many other observations can be made concerning the simulated operational data and its relevance to operations already experienced or to be encountered in the future. There is a wealth of information contained in the computer reports which illuminate many phases of the production-procurement complex heretofore hidden by lack of actual operating data.

## CONCLUSIONS

A general mathematical model has been developed to simulate variables affecting the supply and demand for pulpwood in an integrated pulp and paper mill. The model was arranged so that inventory policies, production levels, and procurement procedures can be changed; and the corresponding performance of the mill recorded and analyzed over extended periods of time. Use of the model enables new operating policies and procedures to be evaluated and compared under circumstances approximating the complexity of real life.

The model has also proved useful in increasing the awareness of present personnel concerning the many variables involved in the pulpwood supply and demand system, and their relative influence on various aspects of the operation.

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# Fiber Dimensions of Certain Philippine Woods, Bamboos, Agricultural Crops and Wastes, and Grasses. III.

F. N. TAMOLANG, R. R. VALBUENA, B. A. LOMIBAO, C. L. KALAW, T. M. LINDAYEN, and B. C. de VELA

**This article is the third of a series on fiber dimensions and derived values determined at the Philippine Forest Products Research Institute from whole fibers of 64 species, including 47 Philippine broadleaved wood species, two conifers, and eight bamboos. In addition, three agricultural crops, two agricultural wastes, and two common grasses were included, bringing the total to 64 species. In the two previous articles (*11*, *12*), similar data for 116 Philippine broadleaved and three coniferous woods, five bamboos, and one palm were reported. The average dimensions of the fibers of the Philippine broadleaved species covered in this article are, in general, about the same as those of other tropical broadleaved woods and European and North American broadleaved pulpwoods. Like katmon and balikbikan fibers in the previous reports, however, the fibers of five noncommercial species included in this report, namely, apanit, mabunot, pangi, anongo, and taingang-babui were found to be unusual for hardwoods. In millimeters, the average dimensions of the fibers of these five species ranged as follows: length, 2.39 to 3.47 (av., 2.85); width, 0.028 to 0.041 (av., 0.036); cell-wall thickness, 0.008 to 0.012 (av., 0.010); and in lumen width, 0.006 to 0.024 (av., 0.018). For the two conifers, almaciga and Mindoro pine, the average dimensions of the fibers were: length, 5.31 and 4.00 mm.; width, 0.044 mm. for both species; cell-wall thickness, 0.007 and 0.008 mm.; and lumen width, 0.030 and 0.028 mm., respectively. The average dimensions of the fibers of the eight bamboos ranged, in millimeters, as follows: in length, from 1.36 to 2.00 (av., 1.68); in width, from 0.018 to 0.022 (av., 0.021); in cell-wall thickness, from 0.0065 to 0.009 (av., 0.0078); and in lumen width, from 0.002 to 0.007 (av., 0.005). Three agricultural crops were also included, having average values which ranged as follows in millimeters: length, from 2.88 to 4.07 (av., 3.37); width, from 0.008 to 0.023 (av., 0.017); cell-wall thickness, from 0.0025 to 0.006 (av., 0.004); and lumen width, from 0.003 to 0.013 (av. 0.009). For the two agricultural wastes, bagasse and rice straw, the average fiber dimensions measured were as follows: length, 1.35 and 1.14 mm.; width, 0.023 and 0.010 mm.; cell-wall thickness, 0.006 and 0.0035 mm.; lumen width, 0.001 and 0.003 mm., respectively. Cogon and talahib of the grass family had average dimensions in millimeters: length, 1.15 and 1.41; width, 0.012 and 0.015; cell-wall thickness, 0.0045 and 0.0035; and lumen width, 0.003 and 0.008, respectively. In all respects, they are typical of their kinds.**

Presented in this paper, is the third report on fiber dimensions covering 47 additional Philippine broadleaved woods, two conifers, eight bamboos, three agricultural crops, two agricultural wastes, and two common grasses. The first and second reports on the same subject (*11*, *12*) gave similar data for 116 Philippine broadleaved species, three conifers, five bamboos, and one palm.

Muhlsteph (*6*), Runkel (*9*), Regie Industrielle de la Cellulose Coloniale (*8*), von Koeppen and Cohen (*13*), and Haywood (*4*) have all reported on the relationship between fiber dimensions and their suitability for papermaking. Restated briefly, those relations of values derived from fiber dimensions to sheet properties are as follows:

### MUHLSTEPH CLASSIFICATION (6)

*Group 1* includes fibers for which cell-wall area is up to 30% of the fiber cross-sectional area for wood and up to 20% for pulp. Such fibers result in paper of good formation and overall strength.

*Group 2* covers fibers having cell-wall areas ranging from 20 to 80% of total area, as is typical of pulp fibers from conifers, and hence these fibers combine properties of those from woods in the other three groups.

*Group 3* includes fibers with cell-wall area from 30 to 80% for pulp. These fibers are still plastic and give softer sheets than do the fibers in group 1.

*Group 4* covers fibers having cell-wall areas above 80%. These fibers are definitely stiff, giving sheets lower in density and overall strength but higher in tearing resistance than those in group 1.

### RUNKEL RATIO (9)

*In group 1*, fibers having a ratio $(2w/l)$* less than unity are very good for papermaking.

*In group 2*, fibers having a ratio $(2w/l)$ about equal to unity are good for papermaking.

*In group 3*, fibers having a ratio $(2w/l)$ greater than unity are poor for papermaking.

### R.I.C.C.† COEFFICIENTS (8)

The "flexibility coefficient" is the ratio of the lumen width to the width of the fiber. The higher is this coefficient, the higher is the tensile strength.

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* $w$ = width of cell wall; $l$ = width of lumen
† Regie Industrielle de la Cellulose Coloniale.

**Table I. Common and Scientific Names of Species Included in This Report**

| | Common name | Scientific name | Status |
|---|---|---|---|
| A. | Broadleaved Wood: | | |
| 1. | Amugis | *Koordersiodendron pinnatum* (Blanco) Merr. | Commercial |
| 2. | Amunat | *Orophea cumingiana* Vid. | Noncommercial |
| 3. | Anii | *Erythrina fusca* Lour. | Weed |
| 4. | Anongo | *Turpina ovalifolia* Elm. | Noncommercial |
| 5. | Anubing | *Artocarpus ovatus* Blanco | Commercial |
| 6. | Anuling | *Pisonia umbellifera* (Forst.) Seem. | Weed |
| 7. | Apanang | *Neotrewia cumingii* (Muell., Arg.) Pax & K. Hoffm. | Noncommercial |
| 8. | Apanit | *Mastixia philippinensis* Wang. | Noncommercial |
| 9. | Basikong | *Ficus conora* King | Weed |
| 10. | Binuang | *Octomeles sumatrana* Miq. | Noncommercial |
| 11. | Bitanghol | *Calophyllum blancoi* Pl. & Tr. | Commercial |
| 12. | Bolon | *Alphonsea arborea* (Blanco) Merr. | Noncommercial |
| 13. | Brazilian firetree | *Schizolobium excelsum* Vog. | Plantation |
| 14. | Buntan | *Engelhardtia subsimplicifolia* Merr. | Noncommercial |
| 15. | Camachile | *Pithecellobium dulce* (Roxb.) Benth. | Plantation |
| 16. | Dalingdingan | *Hopea foxworthyi* Elm. | Commercial |
| 17. | Dangkalan | *Calophyllum obliquinervium* Merr. | Noncommercial |
| 18. | Duktulan | *Syzygium luzonense* (Merr.) Merr. | Commercial |
| 19. | Earpod | *Enterolobium cyclocarpum* Griseb. | Plantation |
| 20. | Firetree | *Delonix regia* (Boj.) Raf. | Plantation |
| 21. | Kaitana | *Fagara rhetsa* Roxb. | Noncommercial |
| 22. | Kalimatas | *Phaeanthus ebracteolatus* (Presl) Merr. | Noncommercial |
| 23. | Kamatog | *Erythrophleum densiflorum* (Elm.) Merr. | Commercial |
| 24. | Kubili | *Cubilia cubili* (Blanco) Adelb. | Noncommercial |
| 25. | Lamog | *Planchonia spectabilis* Merr. | Commercial |
| 26. | Langarai | *Bruguiera parviflora* (Roxb.) W. & A. | Noncommercial |
| 27. | Lanutan-bagyo | *Gonystylus macrophyllus* (Miq.) Airy Shaw | Noncommercial |
| 28. | Mabunot | *Stemonurus luzoniensis* (Merr.) Howard | Noncommercial |
| 29. | Malbayabas | *Tristania decorticata* Merr. | Commercial |
| 30. | Malatapai | *Alangium longiflorum* Merr. | Noncommercial |
| 31. | Manaring | *Lithocarpus soleriana* (Vid.) Rehd. | Noncommercial |
| 32. | Manggachapui | *Hopea acuminata* Merr. | Commercial |
| 33. | Matang-arau | *Melicope triphylla* (Lam.) Merr. | Noncommercial |
| 34. | Molave | *Vitex parviflora* Juss. | Commercial |
| 35. | Moluccan sau | *Albizzia falcata* (L.) Back. | Plantation |
| 36. | Nilad | *Scyphiphora hydrophyllacea* Gaertn. f. | Noncommercial |
| 37. | Pangi | *Pangium edule* Reinw. | Noncommercial |
| 38. | Pianga | *Madhuca obovatifolia* (Merr.) Merr. | Noncommercial |
| 39. | Rarang | *Erythrina subumbrans* (Hassk.) Merr. | Noncommercial |
| 40. | Saging-saging | *Aegiceras corniculatum* (L.) Blanco | Noncommercial |
| 41. | Sandbox | *Hura crepitans* L. | Plantation |
| 42. | Spanish cedar | *Cedrela odorata* L. | Plantation |
| 43. | Tailed-leaf panau | *Dipterocarpus caudatus* Foxw. | Commercial<br>Commercial |
| 44. | Taingang-babui | *Gonocaryum calleryanum* (Baill.) Becc. | Noncommercial |
| 45. | Tarang | *Helicia loranthoides* Presl | Noncommercial |
| 46. | Teak | *Tectona grandis* L. f. | Plantation |
| 47. | Thick-leaved narig | *Vatica pachyphylla* Merr. | Commercial |
| B. | Conifers | | |
| 1. | Almaciga | *Agathis philippinensis* Warb. | Commercial |
| 2. | Mindoro pine | *Pinus merkusii* Jungh. & De Vr. | Commercial |
| C. | Bamboos | | |
| 1. | Anos | *Schizostachyum lima* (Blanco) Merr. | Noncommercial |
| 2. | Bikal | *Schizostachyum diffusum* (Blanco) Merr. | Weed |
| 3. | Bolo | *Gigantochloa levis* (Blanco) Merr. | Commercial |
| 4. | India bamboo | *Bambusa arundinacea* Willd. | Plantation |
| 5. | Kauayan-china | *Bambusa multiplex* (Lour.) Raeusch. | Plantation |
| 6. | Pole-vault bamboo | *Phyllostachys nigra* Munro. | Plantation |
| 7. | Spineless India bamboo | *Bambusa tulda* Roxb. | Plantation |
| 8. | Yellow bamboo | *Bambusa vulgaris* Schrad. var. striata (Lodd.) Gamble. | Plantation |
| D. | Agricultural Crops | | |
| 1. | Abaca | *Musa textilis* Nee | Plantation |
| 2. | Pineapple | *Ananas comosus* (L.) Merr. | Plantation |
| 3. | Sisal | *Agave sisalana* Perrine | Plantation |
| E. | Agricultural Wastes | | |
| 1. | Bagasse | *Saccharum officinarum* L. | Waste |
| 2. | Rice straw | *Oryza sativa* L. | Waste |
| F. | Grasses | | |
| 1. | Cogon | *Imperata exaltata* Brongn. | Weed |
| 2. | Talahib | *Saccharum spontaneum* L. | Weed |

The "relative fiber length" or slenderness ratio is the coefficient of the length to the width of the fiber. The higher the relative fiber length, the higher is the resistance to tearing.

Both high flexibility coefficient and high relative fiber length are not likely to be found in a single tropical hardwood.

## PROCEDURES

The materials and methods used in this study were substantially the same as in the previous reports (*11*, *12*) with the exception of the species used which are listed in Table I. In the case of agricultural crops and wastes, however, and on two common grasses, sampling was modified slightly. In abaca, composite samples were taken from the leaf sheath only, while in pineapple and sisal, composite samples from the base, middle, and top sections of the leaves were used. For bagasse, composite samples were obtained from both the rind and core, while in rice straw and the two grasses, samples were taken from the stem and leaves.

As usual, the fibers were stained for convenience in making the measurements, particularly the thickness

of the cell-wall. Thickness of the cell-wall was measured directly and the lumen width determined as the difference between the fiber width and twice the cell-wall thickness. The term width is used since the measurements were not made on the transverse sections of the fiber but on the whole fibers.

**Table II. Fiber Dimensions and Derived Values for Samples of Philippine Broad leaved and Coniferous Woods, Bamboos, Agricultural Crops, Agricultural Wastes, and Grasses**

| | *Fiber dimensions (average)* | | | | | | | | *Derived values* | | *Specific gravity of wood*[d] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Length* | | *Width* | | *Lumen width* | | *Cell-wall thickness* | | | | |
| | *mm.* | *C.V.*,[a] *%* | *mm.* | *C.V.*,[a] *%* | *mm.* | *C.V.*,[a] *%* | *mm.* | *C.V.*,[a] *%* | *Muhlsteph group*[b] | *Runkel group*[c] | |
| A. Broadleaved Woods | | | | | | | | | | | |
| 1. Amugis | 1.16 | 15 | 0.025 | 14 | 0.016 | 22 | 0.0045 | 25 | III | 0.56 | .. |
| 2. Amunat | 1.16 | 17 | 0.025 | 17 | 0.015 | 29 | 0.0050 | 23 | III | 0.67 | .. |
| 3. Anii | 1.42 | 17 | 0.034 | 18 | 0.024 | 23 | 0.0050 | 27 | III | 0.42 | .. |
| 4. Anongo | 2.49 | 19 | 0.038 | 23 | 0.024 | 33 | 0.0070 | 23 | III | 0.58 | 0.36 |
| 5. Anubing | 1.51 | 18 | 0.025 | 16 | 0.016 | 28 | 0.0045 | 24 | III | 0.56 | 0.51 |
| 6. Anuling | 0.64 | 16 | 0.036 | 18 | 0.026 | 25 | 0.0050 | 22 | III | 0.38 | 0.21 |
| 7. Apanang | 1.54 | 13 | 0.022 | 20 | 0.011 | 34 | 0.0055 | 16 | III | 1.00 | 0.52 |
| 8. Apanit | 3.47 | 18 | 0.041 | 20 | 0.017 | 38 | 0.0120 | 23 | IV | 1.41 | 0.49 |
| 9. Basikong | 1.33 | 16 | 0.025 | 19 | 0.014 | 27 | 0.0055 | 17 | III | 0.79 | 0.43 |
| 10. Binuang | 1.43 | 18 | 0.038 | 19 | 0.030 | 25 | 0.0040 | 27 | III | 0.27 | 0.23 |
| 11. Bitanghol | 1.20 | 17 | 0.024 | 18 | 0.014 | 29 | 0.0050 | 27 | III | 0.71 | 0.50 |
| 12. Bolon | 1.17 | 16 | 0.021 | 18 | 0.009 | 32 | 0.0060 | 25 | IV | 1.33 | 0.70 |
| 13. Brazilian firetree | 1.23 | 20 | 0.030 | 19 | 0.022 | 26 | 0.0040 | 23 | III | 0.36 | .. |
| 14. Buntan | 1.38 | 15 | 0.041 | 16 | 0.033 | 20 | 0.0040 | 21 | III | 0.24 | .. |
| 15. Camachile | 0.73 | 16 | 0.021 | 15 | 0.012 | 30 | 0.0045 | 31 | III | 0.75 | .. |
| 16. Dalingdingan | 1.13 | 16 | 0.021 | 15 | 0.008 | 42 | 0.0065 | 23 | IV | 1.63 | 0.62 |
| 17. Dangkalan | 1.17 | 18 | 0.019 | 15 | 0.010 | 33 | 0.0045 | 29 | III | 0.90 | 0.65 |
| 18. Duktulan | 1.36 | 16 | 0.022 | 17 | 0.007 | 40 | 0.0075 | 18 | IV | 2.14 | 0.62 |
| 19. Earpod | 0.99 | 19 | 0.030 | 16 | 0.020 | 27 | 0.0050 | 28 | III | 0.50 | 0.36 |
| 20. Firetree | 1.24 | 18 | 0.033 | 17 | 0.025 | 22 | 0.0040 | 27 | III | 0.22 | |
| 21. Kaitana | 1.14 | 13 | 0.030 | 17 | 0.023 | 22 | 0.0035 | 32 | III | 0.43 | .. |
| 22. Kalimatas | 1.15 | 16 | 0.021 | 15 | 0.011 | 31 | 0.0050 | 25 | III | 0.91 | .. |
| 23. Kamatog | 1.54 | 19 | 0.024 | 16 | 0.008 | 43 | 0.0080 | 18 | IV | 2.00 | 0.69 |
| 24. Kubili | 1.10 | 15 | 0.025 | 12 | 0.017 | 20 | 0.0040 | 28 | III | 0.47 | 0.49 |
| 25. Lamog | 1.84 | 18 | 0.024 | 15 | 0.010 | 42 | 0.0070 | 20 | IV | 1.40 | 0.55 |
| 26. Langarai | 1.07 | 16 | 0.024 | 13 | 0.005 | 48 | 0.0095 | 14 | IV | 3.80 | .. |
| 27. Lanutan-bagyo | 1.46 | 18 | 0.033 | 20 | 0.021 | 29 | 0.0060 | 19 | III | 0.57 | 0.50 |
| 28. Mabunot | 3.32 | 19 | 0.035 | 19 | 0.011 | 39 | 0.0120 | 15 | IV | 2.18 | 0.34 |
| 29. Malabayabas | 1.12 | 14 | 0.021 | 16 | 0.003 | 23 | 0.0009 | 20 | IV | 6.00 | 0.94 |
| 30. Malatapai | 1.35 | 15 | 0.019 | 15 | 0.009 | 31 | 0.0050 | 19 | III | 1.11 | 0.64 |
| 31. Manaring | 1.22 | 16 | 0.022 | 15 | 0.008 | 45 | 0.0070 | 21 | IV | 1.75 | 0.63 |
| 32. Manggachapui | 1.31 | 19 | 0.021 | 15 | 0.008 | 42 | 0.0065 | 24 | IV | 1.63 | 0.63 |
| 33. Matang-arau | 0.89 | 14 | 0.027 | 17 | 0.020 | 22 | 0.0035 | 28 | III | 0.35 | 0.38 |
| 34. Molave | 0.97 | 16 | 0.022 | 14 | 0.012 | 26 | 0.0050 | 18 | III | 0.83 | 0.71 |
| 35. Moluccan sau | 1.11 | 19 | 0.024 | 16 | 0.017 | 23 | 0.0035 | 26 | III | 0.41 | .. |
| 36. Nilad | 1.09 | 14 | 0.022 | 12 | 0.006 | 34 | 0.0080 | 15 | IV | 2.67 | .. |
| 37. Pangi | 2.58 | 14 | 0.039 | 13 | 0.020 | 33 | 0.0095 | 22 | III | 0.95 | 0.48 |
| 38. Pianga | 1.52 | 16 | 0.029 | 16 | 0.014 | 30 | 0.0075 | 21 | III | 1.07 | 0.60 |
| 39. Rarang | 1.48 | 16 | 0.037 | 16 | 0.028 | 20 | 0.0045 | 26 | III | 0.32 | 0.24 |
| 40. Saging-saging | 0.37 | 15 | 0.022 | 13 | 0.010 | 34 | 0.0060 | 17 | III | 1.20 | .. |
| 41. Sandbox | 1.05 | 19 | 0.027 | 19 | 0.019 | 27 | 0.0040 | 28 | III | 0.42 | .. |
| 42. Spanish cedar | 0.98 | 15 | 0.022 | 21 | 0.016 | 26 | 0.0030 | 30 | III | 0.38 | 0.38 |
| 43. Tailed-leaf panau | 1.71 | 16 | 0.028 | 15 | 0.004 | 50 | 0.0120 | 17 | IV | 6.00 | .. |
| 44. Taingang-babui | 2.39 | 17 | 0.028 | 18 | 0.006 | 50 | 0.0110 | 18 | IV | 3.67 | 0.63 |
| 45. Tarang | 2.08 | 14 | 0.033 | 16 | 0.004 | 47 | 0.0144 | 16 | IV | 7.25 | .. |
| 46. Teak | 1.11 | 18 | 0.027 | 16 | 0.017 | 28 | 0.0050 | 19 | III | 0.59 | 0.49 |
| 47. Thick-leaved narig | 1.55 | 16 | 0.022 | 15 | 0.004 | 44 | 0.0090 | 16 | IV | 2.67 | 0.63 |
| B. Coniferous Woods | | | | | | | | | | | |
| 48. Almaciga | 5.31 | 31 | 0.044 | 22 | 0.030 | 30 | 0.0070 | 28 | II | 0.47 | 0.44 |
| 49. Mindoro pine | 4.00 | 23 | 0.044 | 18 | 0.028 | 42 | 0.0080 | 33 | II | 0.57 | .. |
| C. Bamboos | | | | | | | | | | | |
| 50. Anos | 1.67 | 28 | 0.022 | 22 | 0.004 | 41 | 0.0090 | 25 | ... | .. | .. |
| 51. Bikal | 2.00 | 35 | 0.021 | 19 | 0.007 | 41 | 0.0070 | 26 | ... | .. | .. |
| 52. Bolo | 1.80 | 32 | 0.022 | 25 | 0.006 | 70 | 0.0080 | 30 | ... | .. | .. |
| 53. India bamboo | 1.73 | 35 | 0.022 | 26 | 0.006 | 77 | 0.0080 | 30 | ... | .. | .. |
| 54. Kauayan-china | 1.36 | 31 | 0.018 | 23 | 0.002 | 41 | 0.0080 | 26 | ... | .. | .. |
| 55. Pole-vault bamboo | 1.86 | 25 | 0.019 | 21 | 0.006 | 76 | 0.0065 | 27 | ... | .. | .. |
| 56. Spineless India bamboo | 1.45 | 30 | 0.020 | 22 | 0.005 | 69 | 0.0075 | 29 | ... | .. | .. |
| 57. Yellow bamboo | 1.60 | 30 | 0.020 | 23 | 0.004 | 61 | 0.0080 | 29 | ... | .. | .. |
| D. Agricultural Crops | | | | | | | | | | | |
| 58. Abaca | 3.15 | 94 | 0.020 | 21 | 0.013 | 34 | 0.0035 | 46 | ... | .. | .. |
| 59. Pineapple | 4.07 | 23 | 0.008 | 18 | 0.003 | 24 | 0.0025 | 23 | ... | .. | .. |
| 60. Sisal | 2.88 | 34 | 0.023 | 21 | 0.011 | 39 | 0.0060 | 23 | ... | .. | .. |
| E. Agricultural Wastes | | | | | | | | | | | |
| 61. Bagasse | 1.35 | 35 | 0.023 | 27 | 0.011 | 61 | 0.0060 | 26 | ... | .. | .. |
| 62. Rice straw | 1.14 | 35 | 0.010 | 15 | 0.003 | 42 | 0.0035 | 25 | ... | .. | .. |
| F. Grasses | | | | | | | | | | | |
| 63. Cogon | 1.15 | 31 | 0.012 | 23 | 0.003 | 46 | 0.0045 | 27 | ... | .. | .. |
| 64. Talahib | 1.41 | 52 | 0.015 | 16 | 0.008 | 40 | 0.0035 | 26 | ... | .. | .. |

[a] Coefficient of variation.
[b] Based on transverse area of cell-wall expressed as percentage of the transverse area of the fiber.
[c] Twice thickness of cell-wall divided by the diameter (width) of the lumen.
[d] Pased on green volume and ovendry weight

Table III. Distribution of Lengths of Fibers from Samples of Philippine Broadleaved and Coniferous Woods, Bamboos, Agricultural Crops Including Wastes, and Grasses (in per cent)

| Interval, mm. | Saging-saging | Anuling | Camachile | Matang-arau | Molave | Langarai | Nilad |
|---|---|---|---|---|---|---|---|
| 0.20–0.39 | 66.83 | 1.00 | ... | ... | ... | ... | ... |
| 0.40–0.59 | 33.17 | 35.33 | 15.33 | 1.00 | 2.00 | 0.50 | 0.33 |
| 0.60–0.79 | ... | 57.00 | 57.00 | 21.33 | 20.22 | 4.67 | 2.17 |
| 0.80–0.99 | ... | 6.67 | 25.67 | 56.67 | 38.44 | 29.50 | 26.33 |
| 1.00–1.19 | ... | ... | 1.00 | 20.33 | 28.00 | 45.83 | 47.83 |
| 1.20–1.39 | ... | ... | 1.00 | 0.67 | 10.67 | 18.33 | 21.50 |
| 1.40–1.59 | ... | ... | ... | ... | 0.67 | 1.00 | 1.34 |
| 1.60–1.79 | ... | ... | ... | ... | ... | 0.17 | 0.50 |

| Interval, mm. | Sandbox | Spanish cedar | Kalimatas | Bolon | Earpod | Binuang | Dalingdiñgan |
|---|---|---|---|---|---|---|---|
| 0.40–0.59 | 0.33 | 1.22 | 0.17 | 0.11 | 1.33 | 0.22 | ... |
| 0.60–0.79 | 7.67 | 15.67 | 4.00 | 0.78 | 17.67 | 0.78 | 3.00 |
| 0.80–0.99 | 33.00 | 46.44 | 16.33 | 16.68 | 37.00 | 11.00 | 17.67 |
| 1.00–1.19 | 35.33 | 29.44 | 37.17 | 39.44 | 25.34 | 15.22 | 45.33 |
| 1.20–1.39 | 14.33 | 6.22 | 32.82 | 31.00 | 15.22 | 15.68 | 27.00 |
| 1.40–1.59 | 8.67 | 0.89 | 8.17 | 10.00 | 3.00 | 17.78 | 7.00 |
| 1.60–1.79 | 0.67 | 0.12 | 1.17 | 1.44 | 0.33 | 19.00 | ... |
| 1.80–1.99 | ... | ... | 0.17 | 0.44 | ... | 13.22 | ... |
| 2.00–2.19 | ... | ... | ... | 0.11 | 0.11 | 5.44 | ... |
| 2.20–2.39 | ... | ... | ... | ... | ... | 1.22 | .. |
| 2.40–2.59 | ... | ... | ... | ... | ... | 0.44 | . |

| Interval, mm. | Amunat | Kuitana | Kubili | Moluccan sau | Teak | Brazilian firetree | Dangkalan |
|---|---|---|---|---|---|---|---|
| 0.60–0.79 | 4.00 | 1.33 | 5.67 | 6.33 | 4.33 | 3.67 | 3.00 |
| 0.80–0.99 | 22.78 | 25.00 | 25.67 | 22.33 | 22.33 | 14.33 | 18.67 |
| 1.00–1.19 | 33.00 | 41.55 | 39.00 | 37.67 | 39.67 | 28.00 | 32.67 |
| 1.20–1.39 | 28.11 | 24.67 | 24.50 | 25.00 | 23.67 | 28.33 | 32.00 |
| 1.40–1.59 | 10.78 | 6.67 | 4.83 | 8.00 | 9.33 | 16.00 | 11.66 |
| 1.60–1.79 | 1.33 | 0.78 | 0.33 | 0.67 | 0.67 | 9.00 | 1.83 |
| 1.80–1.99 | ... | ... | ... | ... | ... | 0.67 | 0.17 |

| Interval, mm. | Firetree | Malabayabas | Malatapai | Manaring | Basikong | Bitanghol | Duktulan |
|---|---|---|---|---|---|---|---|
| 0.60–0.79 | 2.33 | 1.33 | 0.33 | 0.78 | 1.00 | 2.00 | 0.33 |
| 0.80–0.99 | 10.67 | 27.83 | 8.00 | 13.00 | 6.50 | 17.33 | 4.33 |
| 1.00–1.19 | 29.00 | 51.17 | 23.17 | 27.00 | 20.83 | 25.50 | 18.00 |
| 1.20–1.39 | 39.00 | 17.67 | 36.50 | 32.11 | 32.33 | 31.33 | 34.83 |
| 1.40–1.59 | 18.67 | 1.17 | 23.17 | 18.00 | 25.17 | 11.17 | 27.83 |
| 1.60–1.79 | 4.67 | 0.50 | 8.00 | 7.78 | 12.00 | 2.33 | 11.33 |
| 1.80–1.99 | 0.33 | 0.33 | 0.83 | 1.33 | 2.00 | 0.17 | 2.83 |
| 2.00–2.19 | ... | ... | ... | ... | 0.17 | 0.17 | 0.52 |

| Interval, mm. | Lanutan-bagyo | Thick-leaved narig | Apanang | Manggachapui | Anii | Anubing | Buntan |
|---|---|---|---|---|---|---|---|
| 0.60–0.79 | 0.11 | 0.11 | 0.25 | 3.11 | 0.83 | 0.50 | 1.00 |
| 0.80–0.99 | 4.00 | 2.89 | 2.75 | 14.00 | 7.00 | 4.00 | 9.67 |
| 1.00–1.19 | 11.00 | 7.55 | 8.50 | 20.78 | 16.33 | 12.67 | 20.00 |
| 1.20–1.39 | 22.67 | 19.78 | 30.00 | 26.78 | 24.50 | 21.67 | 20.33 |
| 1.40–1.59 | 32.33 | 21.00 | 27.00 | 21.33 | 23.00 | 22.83 | 25.33 |
| 1.60–1.79 | 24.00 | 27.67 | 17.25 | 11.00 | 17.33 | 19.50 | 19.00 |
| 1.80–1.99 | 4.00 | 17.00 | 3.75 | 2.33 | 8.67 | 12.17 | 3.67 |
| 2.00–2.19 | 1.67 | 4.00 | 0.25 | 0.44 | 2.17 | 5.00 | 0.67 |
| 2.20–2.39 | ... | ... | 0.25 | 0.23 | 0.17 | 1.33 | ... |
| 2.40–2.59 | ... | ... | ... | ... | ... | 0.33 | 0.33 |

| Interval, mm. | Kamatog | Amugis | Pianga | Rarang | Tailed-leaf panau | Lamog | Tarang |
|---|---|---|---|---|---|---|---|
| 0.60–0.79 | 0.67 | ... | ... | ... | ... | ... | ... |
| 0.80–0.99 | 5.33 | 20.67 | 1.33 | 3.56 | 0.11 | 1.33 | ... |
| 1.00–1.19 | 12.33 | 41.67 | 7.00 | 13.89 | 2.67 | 3.00 | 0.33 |
| 1.20–1.39 | 20.33 | 28.66 | 23.00 | 22.44 | 11.67 | 5.18 | 2.00 |
| 1.40–1.59 | 20.33 | 8.33 | 32.00 | 29.00 | 19.33 | 13.50 | 4.00 |
| 1.60–1.79 | 18.67 | 0.67 | 21.67 | 20.78 | 29.00 | 19.83 | 8.67 |
| 1.80–1.99 | 13.67 | ... | 12.33 | 8.22 | 22.66 | 23.33 | 21.33 |
| 2.00–2.19 | 6.44 | ... | 2.33 | 1.56 | 11.11 | 17.83 | 25.34 |
| 2.20–2.39 | 1.44 | ... | 0.34 | 0.33 | 3.00 | 12.00 | 21.67 |
| 2.40–2.59 | 0.45 | ... | ... | 0.22 | 0.44 | 3.17 | 11.00 |
| 2.60–2.79 | 0.12 | ... | ... | ... | ... | 0.83 | 5.00 |
| 2.80–2.99 | 0.11 | ... | ... | ... | ... | ... | 0.33 |
| 3.00–3.19 | 0.11 | ... | ... | ... | ... | ... | 0.33 |

| Interval, mm. | Pangi | Taingang-babui | Anongo | Apanit | Mabunot | Almaciga | Mindoro pine |
|---|---|---|---|---|---|---|---|
| 1.00–1.19 | 0.67 | 0.33 | ... | ... | ... | 1.00 | ... |
| 1.20–1.39 | 0.67 | ... | 1.00 | 0.50 | 0.17 | 0.33 | ... |
| 1.40–1.59 | 0.67 | 2.67 | 1.33 | 0.50 | 1.50 | 0.33 | ... |
| 1.60–1.79 | 5.67 | 5.50 | 4.33 | 0.63 | 0.67 | 0.33 | ... |
| 1.80–1.99 | 8.00 | 10.50 | 9.67 | 0.67 | 1.67 | ... | 1.00 |
| 2.00–2.19 | 10.33 | 14.00 | 12.33 | 1.75 | 2.50 | 0.33 | 1.00 |
| 2.20–2.39 | 9.67 | 16.50 | 13.00 | 2.25 | 3.83 | 0.33 | 1.00 |
| 2.40–2.59 | 12.66 | 17.83 | 17.67 | 5.13 | 4.83 | 1.00 | 1.00 |
| 2.60–2.79 | 15.67 | 16.00 | 15.67 | 4.50 | 6.83 | 2.35 | 2.00 |

**Table III. (*continued*)**

| *Interval, mm.* | *Pangi* | *Taingang-babui* | *Anongo* | *Apanit* | *Mabunot* | *Almaciga* | *Mindoro pine* |
|---|---|---|---|---|---|---|---|
| 2.80–2.99 | 17.33 | 9.33 | 9.33 | 6.87 | 9.67 | 2.00 | 11.00 |
| 3.00–3.19 | 9.33 | 3.83 | 7.67 | 11.00 | 11.83 | 1.67 | 6.00 |
| 3.20–3.39 | 5.00 | 1.84 | 4.67 | 10.25 | 12.50 | 4.67 | 5.00 |
| 3.40–3.59 | 2.67 | 1.17 | 1.67 | 11.38 | 11.32 | 4.39 | 5.00 |
| 3.60–3.79 | 0.67 | ... | 1.33 | 11.75 | 12.83 | 7.00 | 4.00 |
| 3.80–3.99 | 1.00 | 0.50 | 0.33 | 8.87 | 7.00 | 2.67 | 12.00 |
| 4.00–4.19 | ... | ... | ... | 9.25 | 6.33 | 3.67 | 9.00 |
| 4.20–4.39 | ... | ... | ... | 7.25 | 2.33 | 4.00 | 8.00 |
| 4.40–4.59 | ... | ... | ... | 3.75 | 2.67 | 3.33 | 7.00 |
| 4.60–4.79 | ... | ... | ... | 1.88 | 0.67 | 4.00 | 9.00 |
| 4.80–4.99 | ... | ... | ... | 0.85 | ... | 2.67 | 4.00 |
| 5.00–5.19 | ... | ... | ... | 0.50 | 0.33 | 2.67 | 4.00 |
| 5.20–5.39 | ... | ... | ... | 0.25 | ... | 2.67 | 1.00 |
| 5.40–5.59 | ... | ... | ... | 0.13 | 0.17 | 3.67 | 2.00 |
| 5.60–5.79 | ... | ... | ... | 0.13 | 0.34 | 3.67 | 1.00 |
| 4.80–5.99 | ... | ... | ... | ... | ... | 4.00 | 1.00 |
| 6.00–6.19 | ... | ... | ... | ... | ... | 3.00 | 3.00 |
| 6.20–6.39 | ... | ... | ... | ... | ... | 7.33 | 1.00 |
| 6.40–6.59 | ... | ... | ... | ... | ... | 2.00 | ... |
| 6.60–6.79 | ... | ... | ... | ... | ... | 2.00 | 1.00 |
| 6.80–6.99 | ... | ... | ... | ... | ... | 2.33 | ... |
| 7.00–7.19 | ... | ... | ... | ... | ... | 3.67 | ... |
| 7.20–7.39 | ... | ... | ... | ... | ... | 2.67 | ... |
| 7.40–7.59 | ... | ... | ... | ... | ... | 1.67 | ... |
| 7.60–7.79 | ... | ... | ... | ... | ... | 0.67 | ... |
| 7.80–7.99 | ... | ... | ... | ... | ... | 2.33 | ... |
| 8.00–8.19 | ... | ... | ... | ... | ... | 1.00 | ... |
| 8.20–8.39 | ... | ... | ... | ... | ... | 1.33 | ... |
| 8.40–8.59 | ... | ... | ... | ... | ... | 1.33 | ... |
| 8.60–8.79 | ... | ... | ... | ... | ... | 1.00 | ... |
| 8.80–8.99 | ... | ... | ... | ... | ... | 0.67 | ... |
| 9.00–9.19 | ... | ... | ... | ... | ... | 0.67 | ... |
| 9.20–9.39 | ... | ... | ... | ... | ... | 0.33 | ... |
| 9.40–9.59 | ... | ... | ... | ... | ... | 0.67 | ... |
| 9.60–9.79 | ... | ... | ... | ... | ... | 0.33 | ... |
| 9.80–9.99 | ... | ... | ... | ... | ... | 0.67 | ... |
| 10.00–10.19 | ... | ... | ... | ... | ... | 0.33 | ... |
| 10.20–10.39 | ... | ... | ... | ... | ... | ... | ... |
| 10.40–10.59 | ... | ... | ... | ... | ... | 0.33 | ... |

| *Interval, mm.* | *Kauayan-china* | *India bamboo* | *Spineless India bamboo* | *Anos* | *Bolo* | *Yellow bamboo* | *Bikal* |
|---|---|---|---|---|---|---|---|
| 0.40–0.59 | 0.33 | 0.33 | 0.33 | ... | ... | ... | ... |
| 0.60–0.79 | 6.00 | 1.33 | 6.33 | 1.50 | 0.60 | 2.00 | 2.80 |
| 0.80–0.99 | 17.50 | 10.33 | 17.33 | 9.33 | 6.00 | 8.33 | 6.80 |
| 1.00–1.19 | 19.17 | 13.67 | 18.67 | 15.00 | 11.00 | 17.67 | 10.60 |
| 1.20–1.39 | 18.67 | 16.00 | 13.83 | 20.33 | 16.20 | 18.50 | 9.60 |
| 1.40–1.59 | 14.67 | 11.50 | 9.34 | 14.00 | 13.80 | 14.33 | 9.40 |
| 1.60–1.79 | 11.17 | 12.33 | 5.34 | 10.33 | 11.80 | 3.33 | 11.20 |
| 1.80–1.99 | 4.50 | 7.17 | 4.33 | 5.84 | 9.20 | 7.33 | 8.80 |
| 2.00–2.19 | 3.00 | 4.67 | 4.83 | 4.33 | 9.00 | 5.00 | 10.20 |
| 2.20–2.39 | 1.83 | 5.16 | 2.83 | 2.83 | 5.40 | 2.83 | 4.00 |
| 2.40–2.59 | 0.50 | 4.50 | 3.33 | 6.67 | 4.60 | 2.33 | 5.20 |
| 2.60–2.79 | 0.83 | 2.67 | 3.17 | 2.50 | 2.00 | 2.17 | 5.20 |
| 2.80–2.99 | 0.67 | 3.00 | 1.83 | 2.17 | 2.80 | 1.83 | 4.20 |
| 3.00–3.19 | 0.67 | 1.83 | 2.00 | 1.83 | 1.80 | 0.83 | 2.80 |
| 3.20–3.39 | ... | 1.33 | 1.17 | 0.67 | 1.60 | 1.33 | 3.40 |
| 3.40–3.59 | 0.33 | 1.17 | 0.83 | 1.50 | 2.60 | 1.17 | 1.60 |
| 3.60–3.79 | 0.16 | 1.00 | 1.83 | 0.50 | 0.40 | 0.34 | 2.00 |
| 3.80–3.99 | ... | 0.50 | 0.83 | 0.50 | 0.40 | 0.17 | 0.20 |
| 4.00–4.19 | ... | 1.00 | 1.00 | 0.17 | 0.60 | 0.17 | 1.00 |
| 4.20–4.39 | ... | ... | 0.17 | ... | ... | 0.17 | 0.60 |
| 4.40–4.59 | ... | 0.17 | 0.17 | ... | 0.20 | 0.17 | 0.20 |
| 4.60–4.79 | ... | ... | 0.17 | ... | ... | ... | 0.20 |
| 4.80–4.99 | ... | ... | ... | ... | ... | ... | ... |
| 5.00–5.19 | ... | 0.17 | ... | ... | ... | ... | ... |
| 5.20–5.39 | ... | ... | ... | ... | ... | ... | ... |
| 5.40–5.59 | ... | 0.17 | 1.07 | ... | ... | ... | ... |
| 5.60–5.79 | ... | ... | ... | ... | ... | ... | ... |
| 5.80–5.99 | ... | ... | ... | ... | ... | ... | ... |
| 6.00–6.19 | ... | ... | ... | ... | ... | ... | ... |
| 6.20–6.39 | ... | ... | ... | ... | ... | ... | ... |
| 6.40–6.59 | ... | ... | 0.17 | ... | ... | ... | ... |

| *Interval, mm.* | *Pole-vault bamboo* | *Bagasse* | *Rice straw* | *Cogon* | *Talahib* | *Sisal* | *Abaca* | *Pineapple* |
|---|---|---|---|---|---|---|---|---|
| 0.40–0.59 | ... | 0.60 | 5.00 | 7.67 | 5.00 | ... | ... | ... |
| 0.60–0.79 | ... | 12.50 | 10.00 | 21.67 | 10.00 | ... | ... | ... |
| 0.80–0.99 | 2.17 | 19.00 | 24.50 | 24.33 | 10.00 | ... | ... | ... |
| 1.00–1.19 | 7.33 | 17.50 | 22.50 | 15.67 | 21.00 | ... | ... | ... |
| 1.20–1.39 | 13.67 | 14.00 | 21.50 | 11.67 | 16.00 | 1.00 | ... | ... |
| 1.40–1.59 | 12.67 | 9.50 | 7.00 | 3.66 | 14.00 | 5.20 | 1.00 | ... |
| 1.60–1.79 | 12.83 | 7.50 | 3.50 | 4.33 | 8.00 | 2.00 | ... | ... |
| 1.80–1.99 | 13.50 | 6.50 | 2.00 | 2.33 | 4.00 | 7.00 | 1.00 | 2.00 |
| 2.00–2.19 | 13.17 | 5.00 | 1.00 | 1.67 | 4.00 | 10.00 | ... | 1.00 |

Table III. (*continued*)

| *Interval, mm.* | *Pole-vault bamboo* | *Bagasse* | *Rice straw* | *Cogon* | *Talahib* | *Sisal* | *Abaca* | *Pineapple* |
|---|---|---|---|---|---|---|---|---|
| 2.20–2.39 | 7.67 | 1.00 | 1.00 | 1.67 | 2.00 | 6.00 | 5.00 | 2.00 |
| 2.40–2.59 | 5.33 | 4.00 | 0.50 | 1.67 | 1.00 | 10.00 | 5.00 | 2.00 |
| 2.60–2.79 | 5.17 | 1.50 | ... | 0.33 | ... | 5.00 | 12.00 | 5.00 |
| 2.80–2.99 | 3.00 | 0.50 | ... | 1.00 | 1.00 | 9.00 | 9.00 | 5.00 |
| 3.00–3.19 | 1.00 | 0.50 | 0.50 | 1.00 | 1.00 | 8.00 | 11.00 | 4.00 |
| 3.20–3.39 | 1.16 | 0.50 | 1.00 | 0.33 | 1.00 | 7.00 | 10.00 | 6.00 |
| 3.40–3.59 | 0.50 | ... | ... | 0.33 | 1.00 | 3.00 | 12.00 | 13.00 |
| 3.60–3.79 | 0.50 | ... | ... | 0.67 | 1.00 | 4.00 | 3.00 | 9.00 |
| 3.80–3.99 | 0.50 | ... | ... | ... | ... | 2.00 | 9.00 | 6.00 |
| 4.00–4.19 | 0.33 | ... | ... | ... | ... | 9.00 | 2.00 | 8.00 |
| 4.20–4.39 | ... | ... | ... | ... | ... | 5.00 | 3.00 | 2.00 |
| 4.40–4.59 | ... | ... | ... | ... | ... | 3.00 | 4.00 | 5.00 |
| 4.60–4.79 | .. | ... | ... | ... | ... | ... | 2.00 | 4.00 |
| 4.80–4.99 | ... | ... | ... | ... | ... | ... | 2.00 | 3.00 |
| 5.00–5.19 | ... | ... | ... | ... | ... | 1.00 | 2.00 | 3.00 |
| 5.20–5.39 | ... | ... | ... | ... | ... | ... | 1.00 | 7.00 |
| 5.40–5.59 | ... | ... | ... | ... | ... | ... | ... | 1.00 |
| 5.60–5.79 | ... | ... | ... | ... | ... | ... | 2.00 | 3.00 |
| 5.80–5.99 | ... | ... | ... | ... | ... | 2.00 | ... | 2.00 |
| 6.00–6.19 | ... | ... | ... | ... | ... | 1.00 | 3.00 | 3.00 |
| 6.20–6.39 | ... | ... | ... | ... | ... | ... | 1.00 | 2.00 |
| 6.40–6.59 | ... | ... | ... | ... | ... | ... | ... | ... |
| 6.60–6.79 | ... | ... | ... | ... | ... | ... | ... | ... |
| 6.80–6.99 | ... | ... | ... | ... | ... | ... | ... | 1.00 |
| 7.00–7.19 | ... | ... | ... | ... | ... | ... | ... | ... |
| 7.20–7.39 | ... | ... | ... | ... | ... | ... | ... | ... |
| 7.40–7.59 | ... | ... | ... | ... | ... | ... | ... | ... |
| 7.60–7.79 | ... | ... | ... | ... | ... | ... | ... | ... |
| 7.80–7.99 | ... | ... | ... | ... | ... | ... | ... | ... |
| 8.00–8.19 | ... | ... | ... | ... | ... | ... | ... | 1.00 |

Presented in Table II, are all dimensional values obtained, their coefficients of variation, and derived values for the Runkel and Muhlsteph ratios or groupings. The distributions of lengths of fibers are set out in Table III. The ceofficient of variation is the standard deviation divided by the average times 100, as pointed out earlier (*5*, *11*). It is useful for comparing variability of fiber length between species (*7*).

## DISCUSSION

### *Broadleaved Woods*

Fiber dimensions varied considerably by species as expected and as indicated by the data in Table II. In millimeters, fiber length ranged from 0.37 for saging-saging (*Aegiceras corniculatum*) to 3.47 for apanit (*Mastixia philippinensis*); fiber width ranged from 0.019 for malatapai (*Alangium longiflorum*) and dangkalan (*Calophyllum obliquinervium*) to 0.041 for apanit and buntan (*Engelhardtia subsimplicifolia*); cell-wall thickness ranged from 0.003 for Spanish cedar (*Cedrela odorata*) to 0.012 for apanit, mabunot (*Stemonorus luzoniensis*) and tailed-leaf panau (*Dipterocarpus caudatus*); lumen width ranged from 0.003 for malabayabas (*Tristania decorticata*) to 0.033 for buntan.

Five species not now in commercial use, namely, apanit, mabunot, taingang-babui, pangi, and anongo have unusually long fibers for broadleaved woods. According to Runkel's classification, however, the first three species would yield alkaline-cooked pulp of poor overall strength although they would provide good tearing strength and opacity, based on their slenderness ratios ranging from 85 to 95 (*1*, *7*), and Muhlsteph group IV (*6*). Because of their tearing strength and opacity, however, they are possible sources of good pulp for blending with short-fibered pulps that are deficient in these properties.

Under the Runkel system of classification, pangi and anongo would produce alkaline-cooked pulp of intermediate or moderate strength. It is desirable, however, to compare the quality of sulfate pulps made from these species with those made from Benguet and Mindoro pines, as well as with foreign pine pulps.

The average fiber length of the samples of the eight plantation species was 1.09 mm., the range being 0.73 to 1.24. Applying the Runkel system, these eight species would be rated "very good" for papermaking. Put since this system merely indicates the quality of paper expected, it is probable that the pulps of these species may be deficient in tearing resistance and, similarly, in opacity. It is worth while mentioning that these species are fast growing, and attain commercial sizes quickly.

For the 12 commercial species in the list, the average fiber length was 1.37 mm., the range being 0.97 mm. for molave to 1.84 mm. for lamog. By the Runkel system of classification, four out of the 12 species, namely, amugis, anubing, bitanghol, and molave are considered very promising for pulp and papermaking, while the rest are rated "poor," although moderate in tearing resistance and excellent in opacity. Incidentally, all species included in this study belonging to the Dipterocarpaceae are of the latter classification.

Table IV indicates a general similarity of the fiber dimensions of Philippine broadleaved woods with those of other countries which are being used for pulp and papermaking. On the basis of this information, Philippine hardwoods in general should be equally satisfactory for the production of pulps and for papermaking as those from other countries.

Table V presents the groups of fibers according to the classification of the International Association of Wood Anatomists (*3*). Most of these species (74.47%) possess fibers of medium length (0.97 to 1.55). The lower extreme is saging-saging with extremely short fibers (below 0.50 mm.), while apanit and mabunot have extremely long fibers (above 3.00 mm.).

**Table IV. Comparison of Dimensions of Fibers of Broadleaved Woods from Various Areas**

| Origin of wood | Number of species included | Average dimensions, mm. Length Range[a] | Length Average | Width Range[a] | Width Average | Lumen Range[a] | Lumen Average | Cell-Wall Range[a] | Cell-Wall Average |
|---|---|---|---|---|---|---|---|---|---|
| 1. Philippines | 47 | 0.37–3.47 | 1.41 | 0.019–0.041 | 0.027 | 0.003–0.033 | 0.015 | 0.003–0.012 | 0.006 |
| 2. Tropical (*5*) | 13 | 0.92–1.89 | 1.33 | 0.016–0.034 | 0.024 | ... | ... | 0.003–0.014 | 0.006 |
| 3. Amazon (*10*) | 22 | 0.80–1.92 | 1.27 | 0.015–0.040 | 0.027 | ... | ... | ... | ... |
| 4. New Guinea (*13*) | 5 | 0.87–1.62 | 1.19 | 0.015–0.030 | ... | ... | ... | ... | ... |
| 5. Yucatan (*7*) | 13 | 0.69–1.67 | 1.13 | ... | . | .. | ... | ... | ... |
| 6. Tropical (*5*) | .. | 0.30–2.80 | ... | ... | ... | .. | ... | . | ... |
| 7. U.S.A. (*5, 7*) | 12 | 0.74–1.88 | 1.30 | ... | 0.023 | . | .. | . | ... |
| 8. Europe (*5*) | .. | 0.95–1.25 | 1.08 | ... | ... | ... | ... | ... | .. |

[a] Averages of individual species

### *Coniferous Woods*

Two commercial coniferous woods, almaciga and Mindoro pine, are included in this report. The average fiber lengths, in millimeters, are 5.31 and 4.00, respectively (Table II). By the Chi Ling Chen proposed classification of coniferous tracheids (2), the tracheid length of Mindoro pine belongs to the group of medium length (3.01–4.50 mm.), while almaciga is classed under tracheids long (above 4.51 mm.). According to the Muhlsteph grouping, these tracheids are classified in group II and are good for papermaking.

A good natural stand of Mindoro pine abounds in the mountains of Mindoro and Zambales at high elevations but is not readily available for pulping. Almaciga is found in most islands and provinces in forests at medium and high altitudes. The latter is one of the largest trees reported, growing up to 300 cm. in diam. and 60 m. in height. The trunk is straight and cylindrical, 20 to 30 m. to the lowest branch. This species is not cut at present because it usually occurs at elevations making transportation too expensive. Moreover, cutting of this species is restricted since it is the source of Manila copal. However, not all almaciga trees are good yielders of this type of resin; hence, some may eventually find use in the paper industry. Neither of these two conifers is now economically available in substantial amounts for pulping.

**Table V. Some Broadleaved Woods of the Philippines Grouped by Average Fiber Length, According to the Classification of the International Association of Wood Anatomists (*3*)**

| | | |
|---|---|---|
| | Fibers Short (<0.90 mm.) | |
| 1. | Extremely short (<0.50 mm.) | |
| | 1. Saging-saging | 0.37 |
| 2. | Very short (0.51–0.70 mm.) | |
| | 1. Anuling | 0.64 |
| 3. | Moderately short (0.71–0.90 mm.) | |
| | 1. Camachile | 0.73 |
| | 2. Matang-arau | 0.89 |
| | Fibers of Medium Length (0.91–1.60 mm.) | |
| 1. | Molave | 0.97 |
| 2. | Spanish cedar | 0.98 |
| 3. | Earpod | 0.99 |
| 4. | Sandbox | 1.05 |
| 5. | Langarai | 1.07 |
| 6. | Nilad | 1.09 |
| 7. | Kubili | 1.10 |
| 8. | Moluccan sau | 1.11 |
| 9. | Teak | 1.11 |
| 10. | Malabayabas | 1.12 |
| 11. | Dalingdingan | 1.13 |
| 12. | Kaitana | 1.14 |
| 13. | Kalimatas | 1.15 |
| 14. | Amugis | 1.16 |
| 15. | Amunat | 1.16 |
| 16. | Bolon | 1.17 |
| 17. | Dangkalan | 1.17 |
| 18. | Bitanghol | 1.20 |
| 19. | Manaring | 1.22 |
| 20. | Brazilian firetree | 1.23 |
| 21. | Firetree | 1.24 |
| 22. | Manggachapui | 1.31 |
| 23. | Basikong | 1.33 |
| 24. | Malatapai | 1.35 |
| 25. | Duktulan | 1.36 |
| 26. | Buntan | 1.38 |
| 27. | Anii | 1.42 |
| 28 | Binuang | 1.43 |
| 29. | Lanutan-bagyo | 1.46 |
| 30. | Rarang | 1.48 |
| 31. | Anubing | 1.51 |
| 32. | Pianga | 1.52 |
| 33. | Apanang | 1.54 |
| 34. | Kamatog | 1.54 |
| 35. | Thick-leaved narig | 1.55 |
| | Fibers Long (>1.60 mm.) | |
| 1. | Fibers long (>1.60 mm.) | |
| | 1. Tailed-leaf panau | 1.71 |
| | 2. Lamog | 1.84 |
| | 3. Tarang | 2.08 |
| 2. | Fibers very long (2.21–3.00 mm.) | |
| | 1. Taingang-babui | 2.39 |
| | 2. Anongo | 2.49 |
| | 3. Pangi | 2.58 |
| 3. | Fibers extremely long (>3.00 mm.) | |
| | 1. Mabunot | 3.32 |
| | 2. Apanit | 3.47 |

### *Bamboos*

Eight species of bamboo, in addition to the five previously reported (*11*), are discussed in this paper. Of the eight species, three are endemic, namely, anos, bikal, and bolo, while the rest are introduced or exotic species. The average fiber lengths of the three native species ranged from 1.67 to 2.00 mm. (average, 1.83 mm.). Of especial interest is bikal, a climbing bamboo common in both virgin and second-growth forests, particularly the latter. It is considered a weed species at present. It has the longest average fiber length (2.00 mm.) among the eight bamboo species studied. In this respect, it is comparable to kauayan-tinik (12), found by the Institute to produce strong paper. It should be worth while to compare the quality of sulfate pulp made from this bamboo with the excellent pulp that has been made from kauayan-tinik.

Likewise, bolo should be of particular interest to the Philippine papermaking industry not only because of its expected papermaking qualities but also because of its abundance.

For the foreign species, the average fiber length ranged form 1.36 to 1.86 mm. (average, 1.60 mm.). These introduced species were observed to be thriving in the Philippines. Sulfate pulp was made out of pole-vault bamboo by the Institute and found to be comparable with kauayan-tinik.

### *Agricultural Crops*

For the three agricultural crops in the list, the aver-

age fiber length was 3.37 mm. the range being 2.88 to 4.07 mm. Because of their long fibers, these species can furnish some of the long fibers that will be needed to blend with short-fibered pulps in papermaking. Blended pulps of abaca and white lauan (*Pentacme contorta* (Vid.) Merr. and Rolfe), a broadleaved species of medium fiber length, turned out to be good when made into paper by the Institute. At present, abaca, known internationally as Manila hemp, is used primarily in the manufacture of rope but large quantities are available in the form of waste. Apparently, the paper industry would be a profitable outlet for these tremendous wastes.

*Agricultural Wastes*

At present, bagasse and rice straw are considered wastes from the economic standpoint. However, with the prospective mushrooming of pulp and paper mills in the Philippines, useful paper products will, no doubt, eventually be produced from these wastes. For rice straw, the average fiber length is 1.35 and 1.14 mm. for bagasse. These values are greater than those of some of the broadleaved woods. Sugar cane bagasse is already being used in considerable amounts for producing paper in the Philippines and rice straw, which is used in other countries, may also come into such use in this country.

*Grasses*

Two common grasses, cogon and talahib, have fibers of medium length like rice straw and bagasse, averaging 1.15 and 1.41 mm., respectively. A good quality of paper was made from cogon pulp in the Institute. These grasses are found almost everywhere in the Islands and, because of their unlimited supply, they constitute a potential source of supplementary pulps provided the cost of collection can be kept low enough.

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# Cellulolytic Activity of Marine Fungi. Degradation of Ligno-Cellulose Material

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**Uni-clonal cultures of selected wood inhabiting marine Ascomycetes and Deuteromycetes developing on Manila twine in vessels containing 0.1% yeast extract and sea water have shown extensive cellulolytic activity accompanied by significant loss in the tensile strength of the fiber. The residual tensile strength of the twine varied with attack by different fungal species, from 74 to 183 lb., compared with the 260 lb. tensile strength of the uninoculated twines. Because of the close similarity of cordage and wood in proximate analysis, except for the lower lignin content of the former, it is believed that the notable loss of strength of cordage when used as a growth substrate for the various lignicolous sea water fungi is a positive demonstration of the destructive action of these organisms on wood fibers.**

In recent years considerable interest has been shown in the diverse activities of wood inhabiting marine fungi and their biologic and ecologic niche in the degradation of wood and wood products submerged in the sea. Studies in this important aspect of marine biology are directly related to the development of closely allied work in other disciplines such as the microbiology of paper and pulp (*6*). A comparison of data on basic microbial activities, i.e., cellulolytic systems, processes and resultant products of degradation and synthesis, mode and rate of attack, etc., between one environment and another has been extremely useful in the development of knowledge in many comparatively unexplored biological fields.

Previous reports from The Marine Laboratory (*1*, *2*) have demonstrated the presence of cellulolytic mechanisms in various species of lignicolous marine *Ascomycetes* and *Deuteromycetes*. The possible significance of this activity in fundamental marine degradative processes is noteworthy. As marine fungal enzymatic investigations progress, it is imperative to elucidate the interrelationships between the cellulase system and the attack by the particular organism upon the native lignocellulose complex, and to determine whether these fungi are able to initiate *measurable* degradation of wood and cordage.

Though wood, especially balsa, has been used quite effectively in the majority of our growth and cellulolytic tests, a critical evaluation of the degradation, or loss of significant physical characteristics, of wood, especially when submerged in the sea, is extremely difficult. For, in the marine environment, or in sea water cultures, salt encrustation on and within the wood is an important factor, especially in tests incorporating weight loss following fungal attack as a

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criterion of destruction. Slight losses in the weight of the fungal infested wood may be readily obscured by the presence of such salts. Likewise, tests involving the determination of the strength of small wood panels attacked by fungi in pure cultures are subject to con-

*Fig. 1. Fernbach flasks containing coils of Manila twine submerged in yeast extract sea-water broth. Flask on left has been inoculated with a marine fungus*

siderable experimental error. Under natural conditions, where numerous organisms other than fungi, including bacteria and marine animals, are active on the submerged wood, and where deleterious physical factors are of importance, further complications in strength determinations are obvious. In view of these considerations, Manila twine, a lignocellulose material comparable to wood in proximate analysis, has been used in the present study to evaluate the enzymatic activity of selected marine fungi in their degradation of vascular tissue resulting in a loss of strength of the substrate.

## MATERIALS AND METHODS

In each test, 5 coils of Manila twine, each 10 ft. long, were placed in 2-liter Fernbach flasks containing 1100 ml. of 0.1% yeast extract sea-water broth. Under these conditions, most of the fiber was submerged, though the uppermost coil often was slightly above the level of the nutrient medium (Fig. 1).

The Manila was 100% grade F, non-Davao (Tagaon) fiber, taken from standard lots from the Plymouth Cordage Co., Plymouth, Mass. Among the hard fibers, Manila ranks first in the physical characteristics of durability, tensile strength of fibers, and in the length of fibers (*3*). A small amount, 0.7%, of light hydrocarbon oil, "cordage oil" (*ca.* 100 sec. viscosity Saybolt Universal), is added to the fibers during the production of the twine to insure uniformity in the manufactured product. Hence, tensile strength and changes therein can be determined within a reasonable number of breaks.

Prior to inoculation, the flasks of the Manila yeast extract medium were sterilized at 121°C. for 20 min. Stock cultures of the fungi used in these tests (Table I) were grown on a sea water medium containing 1.0% glucose, 0.1% yeast extract, and 1.5% agar. The inoculum for the various test vessels consisted of 5 to 10 ml. of spore and mycelial suspensions from the stock cultures, prepared by flooding individual slant cultures with sterile sea water.

The inoculated flasks were incubated at laboratory temperature, 20 to 25°C., on an intermittent reciprocating shaker apparatus at 60 strokes per min. The period of incubation varied from 23 to 78 days.

Individual flasks were harvested when vigorous fungal growth was evident on the twine and throughout the liquid medium. The presence of reproductive structures was noted. Fungal mycelium was taken aseptically from each flask and transferred to a sea water nutrient medium to verify the uni-clonal growth in each vessel.

**Table I. Species of Ascomycetes and Deuteromycetes Used**

| *Fungus* | *Reference no.* |
|---|---|
| Ascomycetes | |
| *Torpedospora radiata* Meyers | F-187 |
| *Lulworthia floridana* Meyers | F-190 |
| *Ceriosporopsis halima* Linder | F-189 |
| *Antennospora quadricornuta* (Cribb & Cribb) Johnson | F-186 |
| *Lignincola laevis* Höhnk | F-191 |
| *Peritrichospora integra* Linder | F-192 |
| *Peritrichospora* sp. | F-99 |
| *Halosphaeriopsis* sp. | F-115 |
| Deuteromycetes | |
| *Culcitalna achraspora* | F-118 |
| *Humicola halopallonella* | F-123 |
| *Piricauda arcticoceanorum* Moore | F-73 |
| *Helicoma* sp. | F-150, 151 |
| *Alternaria* sp. | F-109 |
| *Cremasteria cymatilis* | F-63 |
| Unidentified marine sp. | F-29 |
| *Pestalotia* sp. | F-260 |

In certain tests, the coils of twine on removal were numbered 1 to 5 to indicate their relative position in the culture vessel, i.e., no. 1 coil was at the surface of the liquid while coils nos. 3–5 and occasionally no. 2, were completely submerged. This method was developed to ascertain if maximum fungal growth on the twine, as determined visually, was correlated with low tensile strength readings. The coils subsequently were transferred to a Pyrex dish in a drying oven at 37°C. for 8 hr. or overnight. Prior to drying, the ends of the twine were tied with an overhand knot to prevent the loss of twist. The dried twine was shipped to the Plymouth Cordage Co. for the tensile strength measurements.

A Model Q Scott-Horizontal testing machine (Scott Testers, Inc., Providence, R. I.), using the 500-lb. scale, was used to determine the tensile strength, or tenacity of the twines. Tensile strength is expressed here as the pounds "pull" recorded at the actual breaking point of the fiber. Twines were secured by two wraps around 2-in. diam. metal capstans on 10-in. centers. The speed of the moving head was set at 12 in. per min. Fifty feet of twine were used for each test. Ten breaks were made in each test, i.e., two breaks on each of the five 10-ft. coils present. A minimum length of 5 ft. per break was required since most of the twine was needed for fastening to the testing machine. Prior to the tensile strength determinations, all specimens were dried at room temperature, or if necessary at 165°F., and then conditioned to

Table II. Tensile Strength Determinations of Uninoculated Manila Twine[a]

| Test no. | Series of coils[b] 1 | 2 | 3 | 4 | 5 | Grand av. |
|---|---|---|---|---|---|---|
| I | 233 | 279 | 245 | 287 | 241 | 257 |
| II | 274 | 291 | 288 | 293 | 253 | 280 |
| III | 265 | 247 | 256 | 259 | 247 | 255 |

[a] Recorded in lb. at breaking strength of the twine.
[b] Each individual series represents the average of two breaks on 10-ft. sections of twine.

equilibrium at 70°F. and 65% R.H. before breaking. A significant loss of strength or "residual tensile strength" is indicated whenever the breaking point of the test twine is below 200 lb.

The filtrate from each Manila vessel was collected separately and filtered through a 03 Selas filter candle to insure a completely cell-free medium. Initial cellulolytic tests were made within 24 hr. of the collection of the individual filtrates. Subsequently, filtrates were stored, with a preservative added, in sterile bottles at refrigerator temperature, 6° to 10°C. The Nelson-Somgyi method (*4*) was used to determine the reducing sugars, RS, of the filtrate and the RS produced during the tests. The experimental procedure, including the amounts and treatment of the cellulosic preparations, Walseth cellulose (*5*) and carbooxymethylcellulose (CMC-50 T), has been described previously (*1*, *2*). The tests with Walseth cellulose, using 100-mg. amounts, were run for 24 hr., while those with 1.0% CMC were run for 1- and 3-hr. periods. All tests were at 50°C., and except for specific pH studies, at pH 6.0. The latter were adjusted with M/15 Sorensen's buffer, made isotonic with sea water by the addition of NaCl.

The amount of glucose in the hydrolysates and in the fungal filtrates was measured with the Glucostat micromethod (Worthington Biochemical Corp., Freehold, N. J.). The Glucostat reagent, containing glucose aerodehydrogenase, is suitable for specific rapid quantitative determinations of glucose.

## EXPERIMENTAL WORK

The average and grand average tensile strength readings of three uninoculated sets, or controls, subjected to sterilization in 1100 ml. 0.1% yeast extract seawater broth at 121°C. for 20 min. are given in Table II. One set was kept in the culture medium for approximately 40 days before testing. No significant

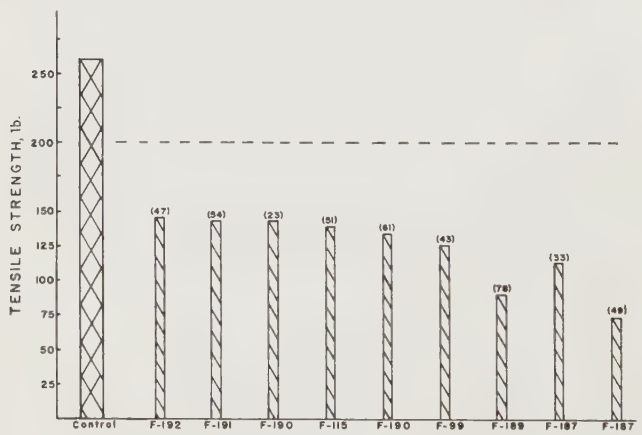


*Fig. 2. Residual tensile strength of Manila twine attacked by species of* Ascomycetes

Control twine at left. The bracketed figures are the ages, in days, of the individual cultures.

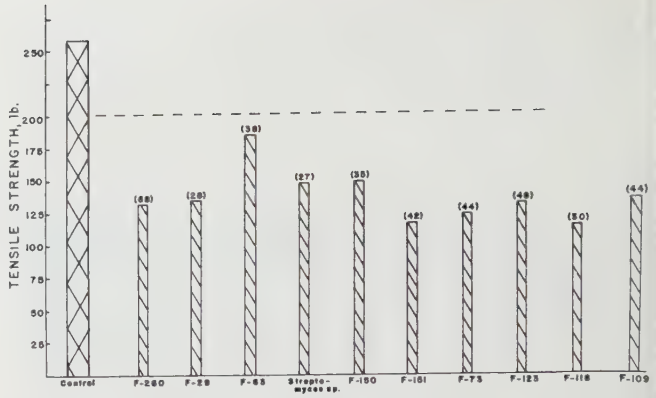


*Fig. 3. Residual tensile strength of Manila twine attacked by species of* Deuteromycetes *and a species of* Streptomyces

Control twine at left.

difference in residual tensile strength was observed between this twine and the material removed and tested immediately after sterilization in the nutrient medium. The grand tensile strength average of an earlier test of uninoculated twine, in addition to those noted in Table II, was 254 lb. Thus, the average of the strength readings of four uninoculated samples, totaling 200 ft. of cordage, was 260 lb. Further analyses were made of the effect of the autoclaving process *alone* (without soaking in the sea water yeast extract medium) upon Manila. Fifty breaks were made with unsterilized twine and 50 breaks with sterilized twine. Samples were taken alternately from bobbins of the same twine, i.e., sterilized 50 ft. samples were alternated with unsterilized samples, to avoid the possibility of comparing one rather strong section with another rather weak section of twine. The sterilized material was then dried and tested in the same manner as that used for the inoculated twines. Subsequent measurements of tensile strength, expressed as the average of 50 breaks, indicated that the sterilization process had no apparent affect on the physical properties of the Manila.

In Figs. 2 and 3 are given the grand average tensile strength of samples of twine attacked by species of *Ascomycetes* and *Deuteromycetes*, respectively. The age of individual cultures, in days, is noted in parentheses.

All of the fungi examined reduced the strength of the twine to less than 200 lb., thus indicating considerable degradation of the fiber. The cordage in the 23-day

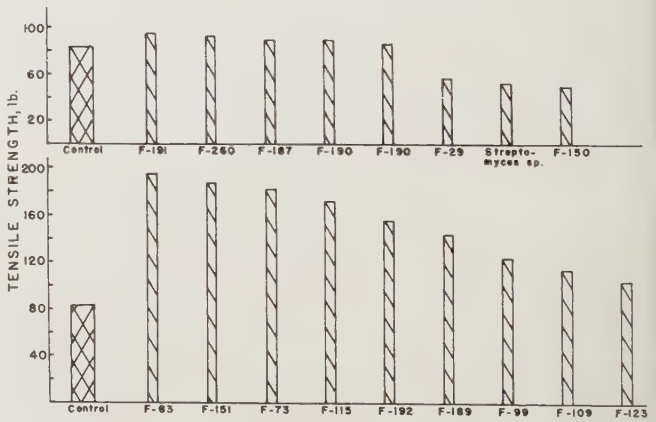


*Fig. 4. Range of tensile strength readings of twine attacked by various fungi*

Control twine at left.

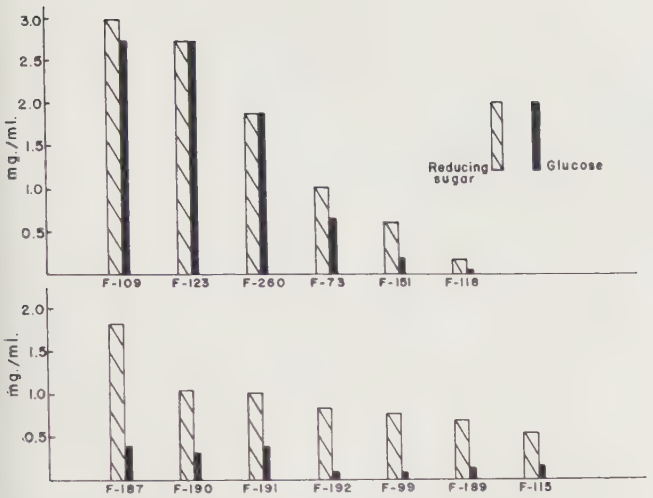


*Fig. 5. Total reducing sugars and glucose produced by fungal filtrates on Walseth cellulose*

Ascomycetes in lower section.

culture of F-190 showed nearly the same grand average tensile strength as did that in the 61-day culture of the fungus. However, in the latter vessel, the pH of the filtrate was 5.6 to 5.8 while that of the filtrate in the 23-day culture was adjusted to 7.5 before inoculation. It is possible that these differences in the initial pH of the filtrates in the two tests affected growth and cellulolytic activity of the organism allowing the 23-day culture to develop cellulase well in advance of the 61-day test. The vigorous attack upon the twine apparent in the 49-day culture of F-187 and in the 78-day culture of F-189 is quite noteworthy. Both of these ascomycetous species exhibited considerably greater fungal activity, in terms of residual tensile strength, than any of the other *Ascomycetes* and *Deuteromycetes* examined. In an earlier test with a 33-day culture of F-187, the breaking strength of the infested twine was 114 lb. Only very slight variation in pounds breaking strength was noted among the five coils attacked by F-187 in the 49-day culture. However, in the 78-day culture of F-189, coil no. 1, which showed the most vigorous fungal growth and perithecial production, exhibited a breaking strength of 9 lb., while coil no. 5, showing only a slimelike development, had a breaking point at 95 lb. In other

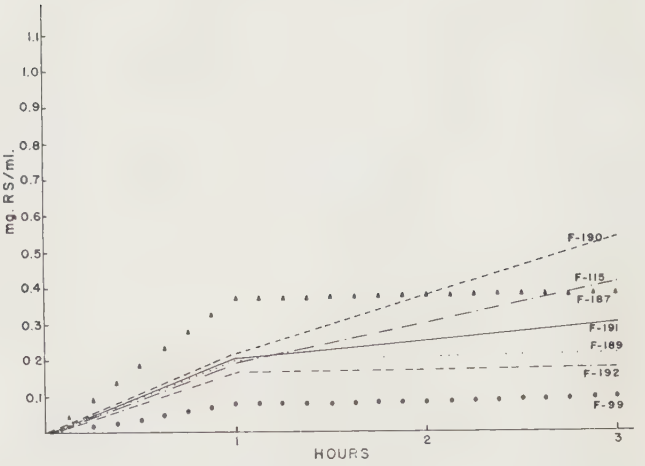


*Fig. 7. Total reducing sugars (RS) produced by ascomycetous fungal filtrates on CMC-50 T for 1 and 3 hr.*

species, the ratio of coil 1 to coil 5, an expression of differences in residual tensile strength, fell between 1:1 and 1:2, thus indicating greater degradation in the surface, or partly exposed, coil.

Similar to the *Ascomycetes* examined, the twine attacked by the deuteromycetous species, with the exception of F-63, had a breaking point of 150 lb. or less. Two nonmarine isolates, F-260 and a species of *Streptomyces*, grown in uniclinal culture for comparative cellulolytic and strength determinations, also exhibited a reduction in the strength of the twine.

Though the fungal infested twine was harvested when extensive growth was indicated, variability in the nature and extent of fungal development on the twine within individual flasks was evident. Twine at the surface of the liquid, usually coils 1 and 2, showed vigorous mycelial growth with extensive discoloration of the fiber. Fruiting structures, when present, occurred in this area of infestation. The submerged fiber, coils 3-5 and occasionally 2–5, exhibited a more scattered fungal attack, gelatinous in nature, and frequently without evident discoloration. Indication of this extreme variability in fungal attack between coils is apparent in the wide range of maximum and minimum readings within individual strength tests (Fig. 4).

The 80-lb. range of the control twine indicates the

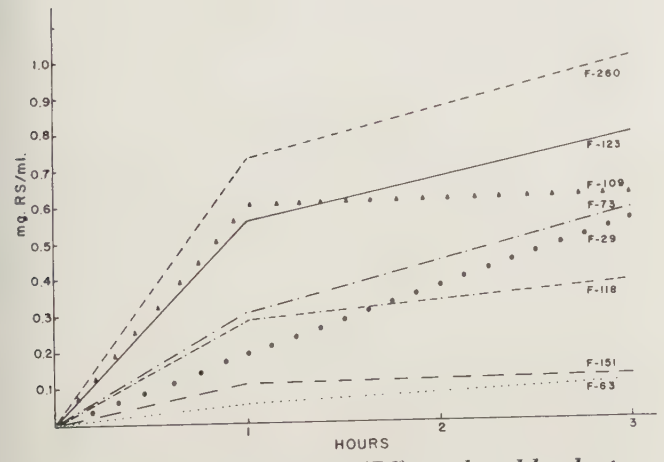


*Fig. 6. Total reducing sugars (RS) produced by deuteromycetous fungal filtrates on CMC-50 T for 1 and 3 hr.*

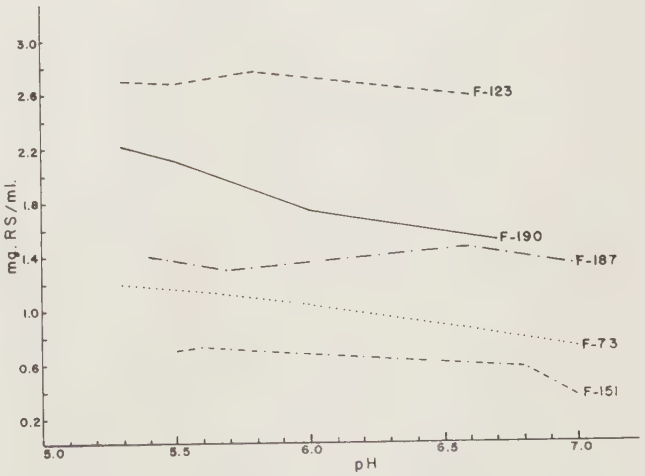


*Fig. 8. Total reducing sugars (RS) produced by selected fungal filtrates on Walseth cellulose at different pH levels*

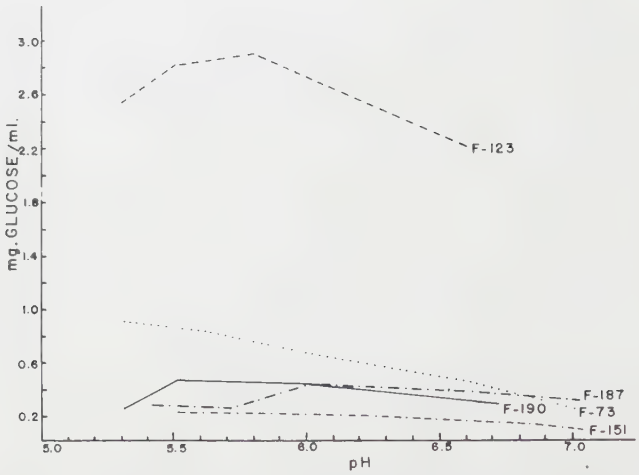


***Fig. 9. Glucose content of the RS fraction produced by selected fungal filtrates on Walseth cellulose at different pH levels***

inherent variability in the test of the 50 ft. of uninoculated twine itself. It is hardly possible to insure uniform fungal attack on all pieces of twine in the culture vessel, especially within a total length of 50 ft. coiled in the bottom of the flask. Nevertheless, since all of the strength determinations of a particular fungus were made from material within a single flask, the relative minimal tensile strength reading of the inoculated twine validly represents the maximal attack or "cellulolytic potential" of the organism.

Along with strength measurements, tests were made of the cellulolytic activity of the filtrate at the time of harvesting of the infested twine. Figure 5 presents cellulase activity of selected cell free fungal filtrates on Walseth cellulose while Figs. 6 and 7 characterize enzymatic activity on carboxymethylcellulose, CMC-50 T. In general, there was a greater total RS production by the deuteromycetous species, especially F-109, F-123, and F-260, than by the ascomycetous isolates. The per cent of glucose in the RS fraction from Walseth cellulose varied considerably, from 10 to 39% for the *Ascomycetes* to 17 to 100% for the *Deuteromycetes* examined. While it is not possible to compare directly the cellulolytic activity of the fungi on Walseth cellulose with that on CMC-50 T, in general, a high RS

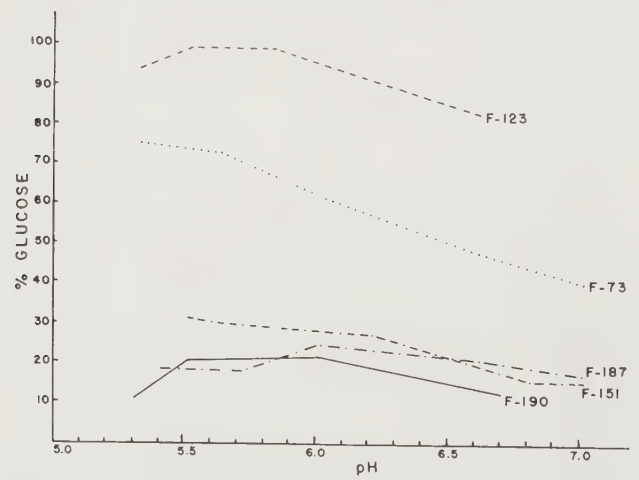


***Fig. 10. Per cent glucose in the RS fraction produced by selected fungal filtrates on Walseth cellulose at different pH levels***

production on the former substrate was associated with a high RS production on the CMC-50 T. Using RS production on the latter material as a criterion of enzymatic activity, F-260 would appear to have greater activity than F-109 or F-123. However, on the Walseth cellulose, the latter two fungi showed considerably greater amounts of RS than F-260.

Selected fungal filtrates were incubated with Walseth cellulose at various pH levels, from 5.3 to 7.0. Figure 8 notes the total amount of reducing sugars (RS) produced, while Figs. 9 and 10, respectively, record the number of milligrams of glucose in the RS fraction and the per cent of glucose represented. F-190, F-73, and F-151 all exhibited slightly greater cellulolytic activity at the lower pH levels. F-73 and F-151 showed a reduction in the percent glucose in the RS fraction as the pH increased, while F-190 and F-123 exhibited a gradual increase in the per cent glucose with increasing pH, followed by a decrease in the per cent glucose from pH 6.2 to 7.0. It is interesting that F-123 showed nearly identical RS production over the entire pH range tested. Similarly, F-187 exhibited excellent RS production from pH 5.4 to 7.0, with maximum at pH 6.0. In F-187, the per cent glucose was identical over the entire pH range, with a slight increase at pH 6.0. The glucose content of the RS fraction in F-123 was approximately 100% (from 85 to 100%), while that of the RS fractions of the other fungi varied from 11 to 76%.

A direct comparison of enzymatic activity and residual tensile strength is not possible, especially since the recorded cellulolytic activity of the fungal filtrates is specifically that of the culture medium in which the fungus had developed, and excludes the role of the enzymes present within the fungal mycelia on and within the infested twine. It is conceivable that a total homogenate of the deteriorated twine, fungal mycelia, and culture medium would reveal considerably greater enzymatic activity than has been indicated in our present tests. From the observations on the breaking point differences between coils 3–5 and coils 1 and 2, it appears that there probably is less loss of fiber strength due to the action of the enzyme fraction in the general culture medium than from the fraction at the immediate site of contact of the fungus with the susceptible substrate.

Our further studies in progress on cellulolytic activity and associated degradation of twine should elucidate various discrepancies between these phenomena as well as contribute valuable information to a better understanding of fungal cellulase systems.

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# The NPIRI Printing Wedge as a Measure of the Commercial Print Quality of Newsprint

S. STEINBERG, C. F. GEFFKEN, and W. K. HERRMANN

**Relative print qualities of five newsprints printed under actual production conditions and in the laboratory using a modified NPIRI printing wedge were determined. Overall agreement between the two methods was good as indicated by a correlation coefficient of 0.934. Within individual panels degree of correlation depended on panel experience in judging production proofs. A Latin square experimental design involving five newsprints, five presses, and five runs was utilized in production. The composite of these runs was called a "Master Press Run." In the laboratory white samples were run at five pressures and at a continuous variable film thickness. Thirteen additional laboratory tests were run on the white samples. These were: Chapman smoothness (glass backing and rubber backing); ink strike-in (Kimberly-Clark); Finnish laboratories E test and H test; Bendtsen hardness: Bendtsen smoothness; rotogravure print test; Chandler and Price letterpress test; Bausch and Lomb opacity; PATRA oil test; Ingersoll glarimeter; Bekk smoothness. The E test had the best agreement with the master press run; the correlation coefficient being 0.964.**

## THE PHILOSOPHY OF THE MASTER PRESS RUN

MANY have either ignored the matter of proving a test by showing its agreement with production, or have altered production runs to a pattern no longer normal, or have attempted analyses from incomplete production runs. A considerable amount of confusion seems to have arisen; perhaps, we should all re-examine this question from the beginning.

Let a bell-shaped curve represent a normal variation of a single paper quality (Fig. 1). Let this quality now be measured with a single instrument. Then, the variations of the instrument itself will have become a part of the resulting data, and the limits probably found to have widened (Fig. 2). Let this quality now be measured by five duplicate instruments, each of which gives the same mean. Probably, this would serve to widen the range of the data a little more (Fig. 3). If each of the five instruments were to give a mean somewhat different from the others, then the result would be five bell-shaped curves, shown expanded in Fig. 4. Of course, the data for the five instruments could be brought to a common mean by the addition or subtraction of constants, if available, and a curve similar to that of Fig. 3 mathematically produced.

On another tack, let us now measure five papers, distinctly different in quality, with a single instrument. There should be five curves similar to those in Fig. 2 showing distinctly different means and little or no overlap (Fig. 5). A single instrument measuring five papers somewhat closer in quality might show means still distinctly apart but more overlap of the curves (Fig. 6).

S. STEINBERG, Plans & Research, The New York *Times;* C. F. GEFFKEN and W. K. HERRMANN, J. M. Huber Corp., New York, N. Y.

Let us now measure with a single instrument a third set of five papers, this time, nearly alike in quality. Then, the means of the five might be separated only slightly, and the amount of overlap would be considerable (Fig. 7). The single instrument could be (a) a single press unit on which conditions were held constant during the printing of five papers, or (b) any single proof press operated under constant conditions.

If the single press unit and the single proof press were so designed that both employed identical conditions of ink film thickness, pressure, etc., in effect, the measurements would be made by similar instruments, and could be expected to give similar sets of curves, as in Fig. 7.

In the laboratory, the authors found that increased pressure made the average of several newsprints print blacker, and the rate of change for a pressure increase was found to vary for each ink film thickness (Fig. 8). Blackness as measured by a reflectometer device is not herein implied to be synonymous with print quality.

Furthermore, it was found that all papers did not appear to respond to a given pressure change in the same manner, or to a like degree. In some instances, there appear to be inversions of blackness as measured by reflectance devices (Figs. 9 and 18).

In the above, it was shown necessary that conditions remain constant throughout the measurement of several papers in order that a press unit qualify as a "single instrument." Unquestionably, the controlled press unit vis-à-vis the controlled proof press would allow an easier achievement of duplication.

## CHOOSING STANDARD CONDITIONS

Not only must the commercial press be controlled, it must also match the conditions of the proof press. Control, but without matching, presumes that the relative positions of ranking in a set of papers will be the same under all conditions—and this does not appear to be so.

Up to this point, we have considered the operation of printing in succession several papers under fixed conditions. In practice, however, the experienced pressman does not use one ink and impression setting on different newsprints. Changes are made as required, and one paper might literally demand more ink or impression. In other words, his single press unit is potentially five instruments (for five papers), and the positions of nearly alike papers, and their ranges, may be displaced (Fig. 10). This is normal press room practice.

*Any* tests that agree well with normal press room practice, with its free interplay of variables, can be considered valid. If the agreement is bad, then the logic of altering normal press runs to force agreement with the tests is just not right.

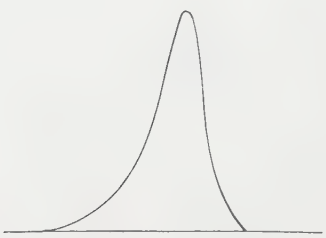


*Fig. 1. Quality variation not measured with instrument*

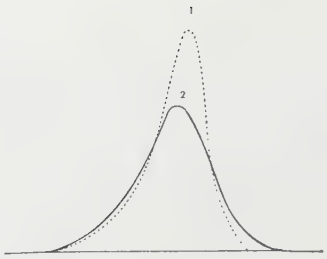



*Fig. 2. Quality variation without instrument vs. with instrument*

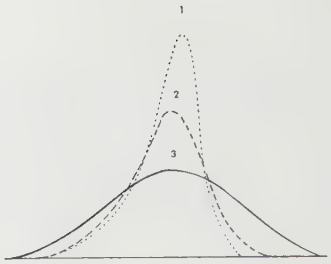



*Fig. 3. Quality variation without instrument vs. with instrument vs. with five duplicate instruments*

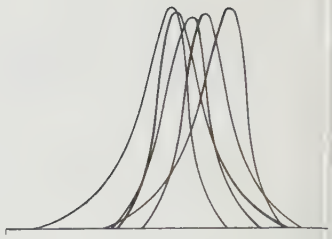


*Fig. 4. A single quality measured with five non-duplicate instruments*

It is neither necessary nor natural to expect the results of a comparison on a single press unit to be the same as those obtained on another unit—or even on the same unit on a repeat. However, it can be anticipated that the *average* result of an adequate number of press comparisons might produce a ranking that is representative of all other averages. This is the concept of the master press run

## SENSITIVITY OF TESTS—AND AGREEMENT

Let us arbitrarily classify all newsprints into ten levels of quality. Select paper from 15 mills, A to O, and divide them into three groups of five each for comparison. Assume that they are listed in their proper levels of quality in the following:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| A | | B | | C | | D | | | E |
| | | F | G | H | I | J | | | |
| | | | K | L | M | N | O | | |

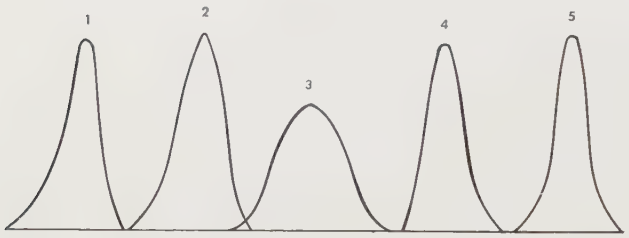



*Fig. 5. Five unlike papers measured with one instrument*

Compare each group of papers by the three types of press runs mentioned above: single, controlled run; single, uncontrolled run; master press run—an average of several, uncontrolled runs.

A master press run average should most precisely rate papers A to E. A single press unit under normal, variable conditions might produce a displacement of one or more of the curves, but the order of ranking should be the same because of the wide spread between mills. Also, the controlled press run, hence, the controlled proof press, could be expected to give the same order of ranking for papers so far apart. If the controlled test can separate into five grades: very poor, below average, average, above average, and very good, it can still serve to very good purpose.

Next, the five mills, F to J, are somewhat closer together, being only one level apart in quality. Again, the master press run average should rate them more precisely than would the single, variable press run. But there is now the added possibility that the order of ranking may differ from the average. Also, the single, controlled run might position F to J in an order differing from both of the others.

As the qualities of the five papers approach one another more closely, mills K to O, the likelihood grows stronger that the master press run average will give an order of ranking with which neither the single, variable, nor the single, controlled runs will agree. Again, the latter two may not match.

How important is it to distinguish between newsprints such as K to O? A mill may wish to learn if a machine or furnish change leads to a better or poorer printing paper. It needs to determine the direction of a displacement even if it is small. Or, a printing plant may wish to distinguish between two newsprints nearly alike in quality. Then, a test that is to be considered good should be capable of meeting this requirement.

Dozens of tests yield reproducible data and allow the classification of newsprints into precise sequences. Though they may provide very exact numbers, however, there is no assurance of their agreement with commercial press runs. For example: preliminary studies by the

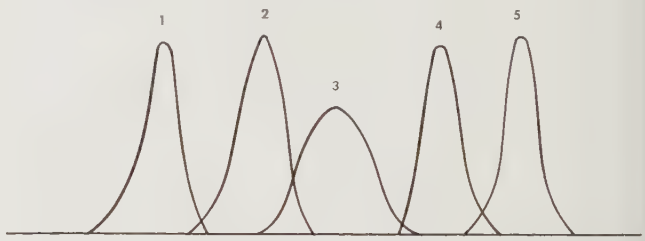



*Fig. 6. Five papers closer in quality measured with one instrument*

authors with reflectance devices on different ink film thicknesses of the wedge gave precise values, but they did not agree with visual appraisal of the wedge, or visual appraisal of the press runs. The visual wedge ranking, although relative, appeared to give good agreement with the press runs. The wedge test, therefore, can have more significance even though it doesn't give values which lie along a numbered scale of quality. We will attempt to show that it can possess good sensitivity, and how a scale can be provided through the use of standards.

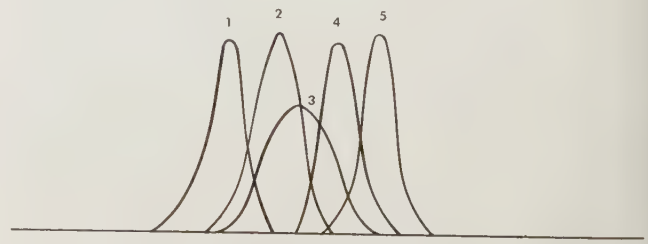



*Fig. 7. Five nearly alike papers measured with one instrument*

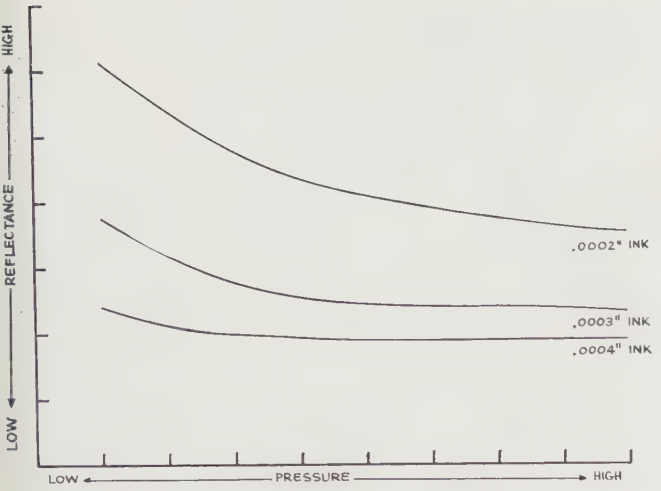



*Fig. 8. Wedge study; per cent reflectance vs. pressure-plotted for three ink-film thicknesses*

## DESIGN OF THE MASTER PRESS RUN

Different orders of ranking are easily produced by press to press variations, especially if one deliberately tries to encompass those of major importance. To force a set of conditions on each run is, in some cases at least, not workable, and in any event, nor normal. If, instead, one can achieve control by the proper design of a group of uncontrolled runs, then the mean for each paper is more apt to be representative of the press room.

Master press run—Latin square arrangement

| | |
|---|---|
| Run no. 1 on first unit: | A-B-C-D-E |
| Run no. 2 on second unit: | B-C-D-E-A |
| Run no. 3 on third unit: | C-D-E-A-B |
| Run no. 4 on fourth unit: | D-E-A-B-C |
| Run no. 5 on fifth unit: | E-A-B-C-D |

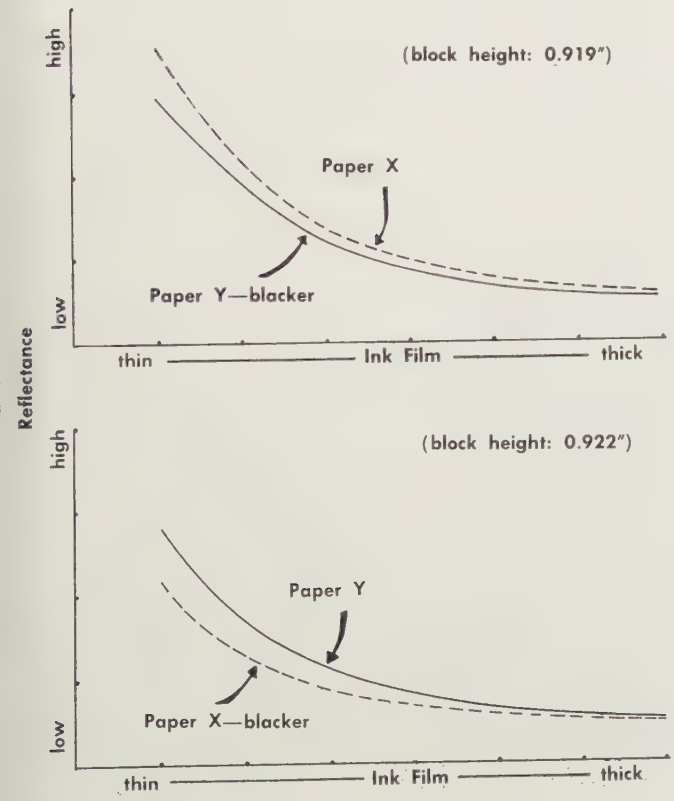



*Fig. 9. Wedge study; a pressure change may produce an inversion in ranking as measured by reflectance*

*Fig. 10. Normal variable press runs may change the ranking of nearly alike papers*

The major variables can be nulled by using:

A different press unit for each run; construction details, ink distributing systems, rollers, blankets, etc., will differ.
Different stereotype plates on each unit.
Varying amounts of stereotype plate wear on each paper.
A different pressman on each unit, hence, a potentially different ink and pressure setting.
A different set of illustrations from each run.
A number of rolls from each mill sufficient to permit averaging out the within-mill paper differences.

Five mills, A to E, very close in print quality were to be graded. We guessed that five press runs might provide good averages for their ranking. To keep within-mill variations to a minimum, each mill supplied five rolls taken from the same position (front, center, or back) of one paper machine, manufactured in succession, and wound wire side out. They were printed in the Latin square design (*1*) and each mill was averaged across the five runs. All runs were at less than 50% R.H. When a roll was run down to a butt 8 to 9 in. in diam., it was removed from the press, 50 turns of paper were discarded, and large white samples were folded into quarters and quickly sealed in 0.004-in. polyethylene bags.

## SELECTING AND JUDGING THE PRESS RUN SPECIMENS

These observers felt that it might be fundamentally wrong to limit comparisons only to certain portions of the printed matter, such as solids only, or specific halftone areas only, etc., until some current investigations along these lines were completed. It was considered more advisable to include as many halftones and solids as possible—coarse illustrations as well as those with fine detail.

The print specimens included flowers, outdoor scenes, people, drawings, airplanes, benday screens, solid type, light prints and dark, advertising and editorial material, first and second impression side printings, etc.

The sizes of the specimens were as small as conveniently possible, and ranged from $1^1/_2 \times 2^1/_2$ in. up to $4 \times 8^1/_2$ in. If a large print is given to two judges, one of them may rank from one area, while the other may rank from a completely different area. Attention may be directed to the many varieties of printed matter either by cutting the larger illustrations apart, or by choosing small ones.

Three specimens per roll times five runs gave a total of 15 different prints for each side for each mill. They were cut out and mounted individually on white cards, then presented to each judge in sets of five—one for each mill. The best print was scored one, while the worst was scored five; one complete set totaled 15 points. (One panel elected to designate equals rather

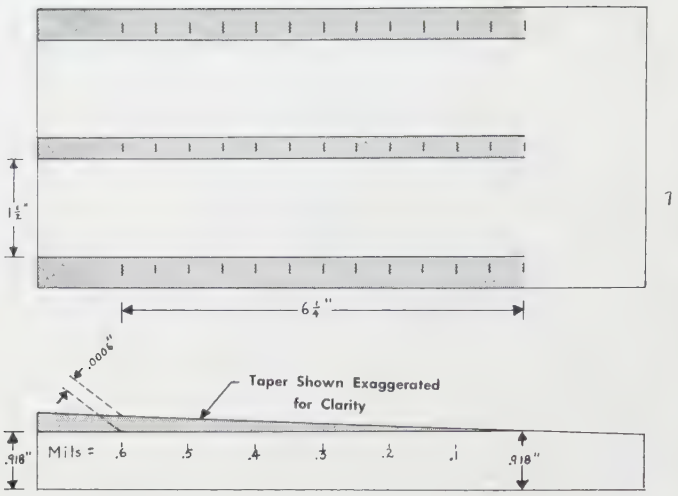



*Fig. 11. NPIRI-designed printing wedge shown from top and cross-sectional views*

The ink-bearing or printing level is 0.918 in. throughout. The wedge-shaped channels are created by adding shoulders, shown shaded, tapering from 0.918 to 0.9186 in.

than give each print a definite number when they were close; in such a case, five equals would give each a score of 3; etc.)

It is the opinion of the authors, based on this as well as previous studies, that judges should be trained. It may not be wise to too closely tutor a prospective judge for then he may see through the eyes of his instructor. If we want the opinion of "everyman," should he not be self-trained? When first confronted with a set of prints, a trainee may have trouble in making his selection. After a number of very brief sessions with specimens, wider apart at first, then closer together, he will become very conscious of fine detail, white specks, evenness, wire mark, or whatever it is that enters into everyman's judgment of printing. It may be better to average the opinions of several judges rather than rely on only one. *Some* people engaged in printing production are apt to be biased because of their specialized knowledge. Also the authors prefer to exclude themselves when possible. Instructions should be held to a minimum. Because of color differences of our five newsprints, and since mills can generally match, the judges were directed to ignore the color as much as possible, and make their selections on the basis of print quality.

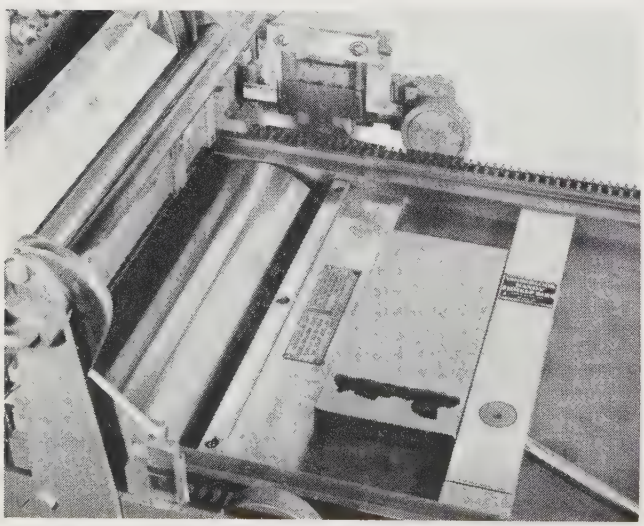


*Fig. 12. The wedge block with an excess of ink on the shallow end*

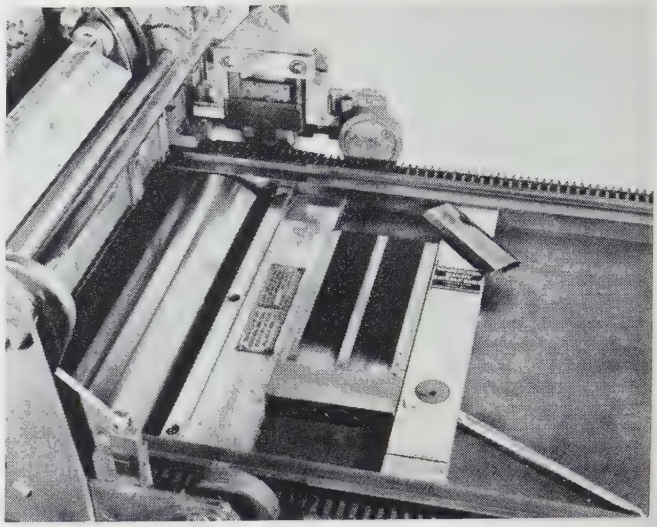


*Fig. 13. The knife, resting on lockup bar, has been used to drawdown the ink to the deep end*

Twenty judges were used:

Subpanel 1 had the four most highly trained judges; part of their regular work consists of judging all types of printing.

Subpanel 2 was a single judge, very skilled in letterpress printing and, principally, in the comparison of solids.

Subpanel 3 contained three judges; one was very skilled, while the other two had 10 and 30 min. of training.

Subpanel 4 contained six paper chemists with some judging experience, but mainly of solids.

Subpanel 5 used three judges skilled in the examination of rotogravure prints, but only semiskilled in the examination of letterpress.

The "grand" panel is the total of the 17 judges above; it is presumed that the training methods of the individuals was quite diverse.

Subpanel 6 was composed of three judges with almost no prior judging experience; no training, and no instructions at all were given them.

In the presentation of data, the findings of subpanel 1, the grand panel, and subpanel 6 will be compared; that is, highly trained versus average trained versus untrained.

## THE PRINTING WEDGE TEST

The wedge is a modification of a device called the Grindometer, used for determining unground pigment

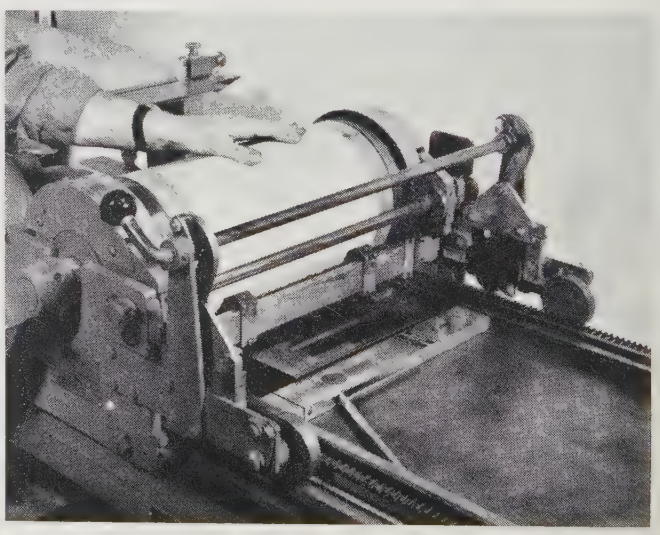


*Fig. 14. Note that the block is positioned across the direction of printing*

or grit. Both were made according to designs specified by the National Printing Ink Research Institute (NPIRI). Other investigators, as well as the NPIRI, have used the wedge and Grindometer for other ink as well as paper tests (*2*).

The wedge is drawn, not to scale, in Fig. 11. The printing level is type-high, 0.918 in. from one end of the block to the other. The wedge-shaped channels are

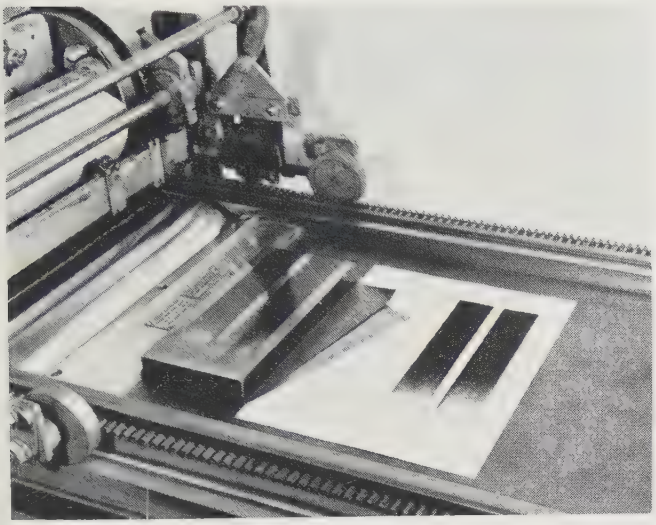


*Fig. 15. Shows the block, metal shims for increasing pressure, and a specimen print*

created by adding shoulders which rise above the 0.918-in. height from zero to approximately 0.0006 in., or 0.6 mil. Figure 12 shows an excess of ink placed on the shallow end of the wedge. By means of a precisely ground knife, upper right Fig. 13, a drawdown of the ink is made in the direction of the deep end. Prospective users of the device should regrind conventional inks to reduce oversize pigment agglomerates. It was found that if objectionable scratches appeared in the fine ink, a second pass with the knife, without reinking, would serve to remove them. As a consequence, to maintain uniformity, a second pass was given in every case.

Actual weighings after two drawdowns showed the ink film thickness to range from zero to 0.4. The normal commercial printing thickness range, 2 to 6 $\mu$, is equivalent to the 0.125- to 0.375-mil portions of *this* block. Figure 14 shows how the block is positioned *across* the direction of printing. The printing, this way, is letterpress. If the block were turned 90°, it would become intaglio.

A pressure variation was included to make the test more nearly comparable to normal printing experience. By using metal shims under the block, Fig. 15, prints were made at five pressures for each paper: 0.918 in. through 0.922 in. This gave 25 wedge prints per side per mill. At each pressure level, they were mounted in sets of five to a card (one for each mill), and masked with white paper. They were scored the same as the press prints: 1 for the best, while the worst was 5.

(Lehigh University has designed a block that prints three channels at different pressures, and another that prints six channels at different pressures. Their manufacture is comparatively difficult. The authors prefer a set of blocks, which may also be printed in one operation—see Summary.)

***Selecting and Judging the Wedge Test Prints***

In a preliminary study, the authors made four or five duplicate prints at each pressure step. They were laid out side by side, and the average or typical print chosen for judging. Because this made the test cumbersome and an analysis of findings indicated it to be unnecessary, only a single print was made at each step for this study. A mean across several rolls serves to average out or null this variable.

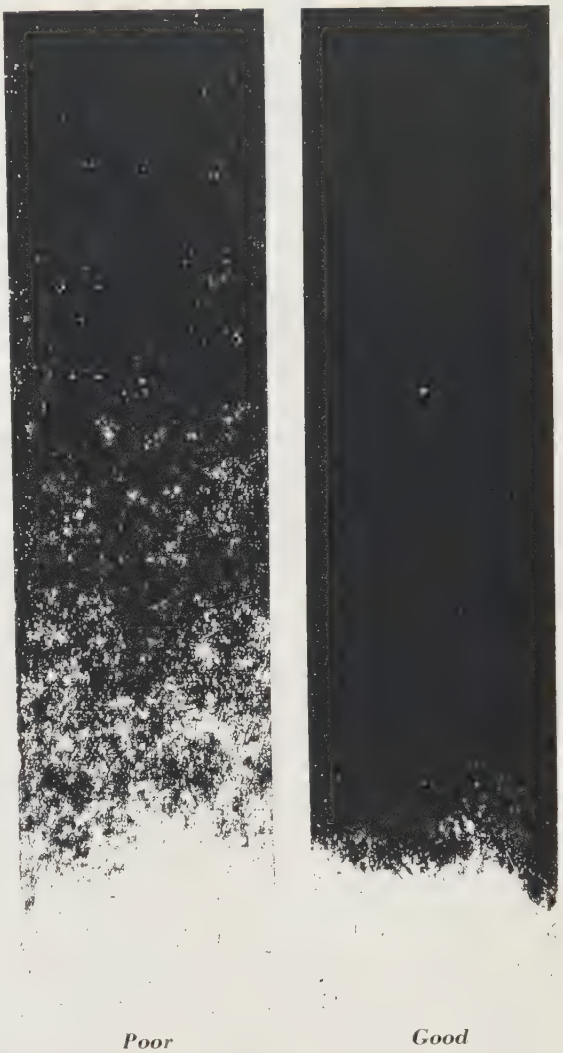



*Fig. 16. An exaggerated comparison of wedge prints*

An exaggerated comparison of a good against a poor newsprint is shown in Fig. 16. The eye appears to be more sensitive to small variations in ink uniformity—it will easily pick out white specks, etc.—than to variations in the degree of blackness. Blackness may be involved, but its role appears to be secondary, at most.

An extremely poor newsprint exhibits breaks in the black even in an ink film thicker than normal press operations will allow. On the other hand, a paper of of very good print quality can achieve a uniform, unbroken ink lay at film thickness below normal. Since their rating by an observer is quick and almost automatic, instructions to the judges were nearly nil, not-

**Table I. Wire Side Correlations—Subpanel 1 Only**

| | Mill | Mean score: Press | Mean score: Wedge | Correlation coeff. | Ranking: Press | Ranking: Wedge |
|---|---|---|---|---|---|---|
| Press run no. 1, on unit no. 1, printed in the order: A-B-C-D-E | A | 3.111 | 3.50 | +0.447 | 2 | 4 |
| | B | 3.667 | 4.15 | | 4 | 5 |
| | C | 1.222 | 2.40 | | 1 | 2 |
| | D | 3.222 | 1.60 | | 3 | 1 |
| | E | 3.778 | 3.35 | | 5 | 3 |
| Press run no. 2, on unit no. 2, printed in the order: B-C-D-E-A | A | 3.333 | 1.55 | −0.0634 | 3 | 1 |
| | B | 4.000 | 4.50 | | 4 | 5 |
| | C | 1.889 | 2.10 | | 2 | 2 |
| | D | 1.556 | 4.30 | | 1 | 4 |
| | E | 4.222 | 2.55 | | 5 | 3 |
| Press run no. 3, on unit no. 3, printed in the order: C-D-E-A-B | A | 3.444 | 4.30 | +0.536 | 4 | 5 |
| | B | 4.778 | 3.65 | | 5 | 4 |
| | C | 2.333 | 2.40 | | 2 | 2 |
| | D | 1.556 | 2.80 | | 1 | 3 |
| | E | 2.889 | 1.85 | | 3 | 1 |
| Press run no. 4, on unit no. 4, printed in the order: D-E-A-B-C | A | 3.667 | 4.15 | +0.305 | 4 | 5 |
| | B | 2.333 | 3.40 | | 2 | 4 |
| | C | 2.445 | 1.25 | | 3 | 1 |
| | D | 2.222 | 3.00 | | 1 | 2 |
| | E | 4.333 | 3.20 | | 5 | 3 |
| Press run no. 5, on unit no. 5, printed in the order: E-A-B-C-D | A | 3.222 | 3.15 | −0.171 | 3 | 3 |
| | B | 4.556 | 4.10 | | 5 | 4 |
| | C | 1.555 | 2.25 | | 1.5 | 2 |
| | D | 4.111 | 1.10 | | 4 | 1 |
| | E | 1.556 | 4.40 | | 1.5 | 5 |
| | | | | | Rank sums: | |
| Mean of five runs, on five press units, designed to null all known variables | A | 3.356 | 3.33 | +0.976 | A 16 | A 18 |
| | B | 3.866 | 3.96 | | B 20 | B 22 |
| | C | 1.889 | 2.08 | | C 9.5 | C 9 |
| | D | 2.533 | 2.56 | | D 10 | D 11 |
| | E | 3.356 | 3.07 | | E 19.5 | E 15 |
| Statistical calculations of agreement between press runs: | | | | | | |
| $\chi^2 r$ = probability of rank sums by chance, 1 in— | | | | | 11 | 15 |
| $W$ = coefficient of concordance (perfect = 1.0) | | | | | 0.406 | 0.440 |

**Table II. Wire Side Correlations—All Panels**

| Panel no. | No. of judges | Mill | Mean score: Press | Mean score: Wedge | Correlation coeff. | Ranking: Press | Ranking: Wedge |
|---|---|---|---|---|---|---|---|
| 1 | 4 | A | 3.356 | 3.330 | | 3.5 | 4 |
| Most highly skilled; regular comparison of all types of printing | | B | 3.866 | 3.960 | | 5 | 5 |
| | | C | 1.889 | 2.080 | | 1 | 1 |
| | | D | 2.533 | 2.560 | | 2 | 2 |
| | | E | 3.356 | 3.070 | 0.976 | 3.5 | 3 |
| 2 | 1 | A | 3.200 | 3.040 | | 3 | 3 |
| | | B | 3.900 | 3.700 | | 5 | 5 |
| Skilled in judging; largely, solids | | C | 1.933 | 2.360 | | 1 | 1 |
| | | D | 2.567 | 2.580 | | 2 | 2 |
| | | E | 3.400 | 3.320 | 0.982 | 4 | 4 |
| 3 | 3 | A | 3.289 | 3.560 | | 4 | 4 |
| | | B | 3.644 | 3.747 | | 5 | 5 |
| Mixed panel; one judge skilled, two trained very briefly | | C | 2.556 | 2.267 | | 2 | 1 |
| | | D | 2.244 | 2.613 | | 1 | 2 |
| | | E | 3.267 | 2.813 | 0.829 | 3 | 3 |
| 4 | 6 | A | 3.300 | 3.573 | | 4 | 4 |
| | | B | 3.711 | 3.648 | | 5 | 5 |
| Paper chemists with some judging experience, mainly solids | | C | 2.133 | 2.393 | | 1 | 1 |
| | | D | 2.578 | 2.573 | | 2 | 2 |
| | | E | 3.278 | 2.813 | 0.880 | 3 | 3 |
| 5 | 3 | A | 3.392 | 3.247 | | 3 | 4 |
| | | B | 3.783 | 3.887 | | 5 | 5 |
| Skilled in examination roto print test proofs; semiskilled letterpress | | C | 2.233 | 2.153 | | 2 | 1 |
| | | D | 2.192 | 2.593 | | 1 | 2 |
| | | E | 3.400 | 3.120 | 0.935 | 4 | 3 |
| Grand Panel | 17 | A | 3.324 | 3.425 | | ΣA 17.5 | ΣA 19 |
| | | B | 3.755 | 3.783 | | ΣB 25 | ΣB 25 |
| The five panels above are treated as a single, large panel | | C | 2.176 | 2.253 | | ΣC 7 | ΣC 5 |
| | | D | 2.420 | 2.581 | | ΣD 8 | ΣD 10 |
| | | E | 3.325 | 2.958 | 0.949 | ΣE 17.5 | ΣE 16 |
| Statistical calculations of agreement between panels: | | | | | | | |
| $\chi^2 r$ = probability of rank sums by chance, 1 in— | | | | | | 833 | 1000+ |
| $W$ = coefficient of concordance (perfect = 1.0) | | | | | | 0.902 | 0.968 |
| 6 | 3 | A | 3.622 | 3.240 | | 5 | 4 |
| | | B | 3.578 | 3.867 | | 4 | 5 |
| Almost no judging experience; no training; no instructions | | C | 2.644 | 2.426 | | 2 | 1 |
| | | D | 1.756 | 2.640 | | 1 | 2 |
| | | E | 3.400 | 2.827 | 0.677 | 3 | 3 |

withstanding the fact that not one of the 17 judges in grand panel had ever before rated wedge prints.

* * *

The wedge test, with its variable ink and pressure, is in the nature of being a complex or multi-instrument. In the next section, its agreement with the multi-instrument press will be analyzed. Wire sides, felt sides, wire versus felt, and the mean of felt and wire

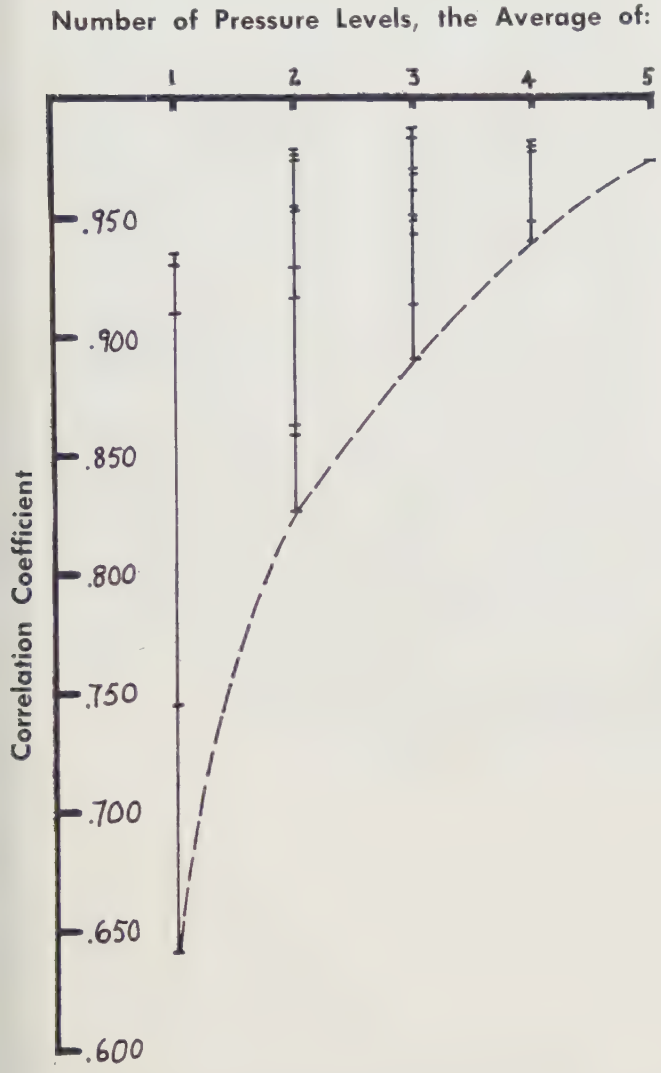



***Fig. 17. Subpanel 1, wire side only. The master press run correlated against all 31 possible combinations of wedge pressures***

Any combination of three pressures would have produced coefficients of 0.9 or better.

will be compared. Then, 13 tests other than the wedge will be compared to the master press run.

## PRESENTATION OF DATA—ANALYSIS OF WIRE SIDES

The prints were judged in sets of five, with the best scoring 1, and the worst 5. Papers perceptibly different would give mean scores close to the proportion 1:2:3:-4:5. Papers nearly alike should each average closer to 3.

Table I shows data for the highly trained subpanel 1 only. The last two columns show the rankings from run to run of the press and wedge. Two statistical values indicating the agreement between runs were computed from the sum of the five rankings. Chi-square-times-r and concordance values show only a "weak" agreement, as anticipated (*3*).

The column, mean press score, lists the exact averages of three press print comparisons per judge; mean wedge score averages five wedge prints (one for each pressure) per judge. These values "weight" the relative quality of the papers much more exactly than do the rankings. Also, they permit the calculation of correlation coefficients. Note that the range for the latter for single runs was from −0.171 to +0.536, whereas the coefficient for the mean of five runs improved to 0.976. It clearly shows the need for a master press run.

A very expert observer expressed the opinion that the differences between the best and poorest printing of the five test papers were very slight by their standards. This means that paper variations alone could have made the rankings from run to run different. Then, it certainly should not be normal expectancy to get duplication between single runs, especially when press variables are exaggerated (as outlined in the Design of the Master Press Run). Similarly, differences in individual wedge print rankings arise from paper and test variations.

Notwithstanding the effort to obtain "equal" rolls from each mill, it will be shown, later in this section, that there was a highly significant difference between the rolls within mills. Add to that the statement that fundamental studies of transfer properties of news ink on newsprint conducted by the National Printing Ink Research Institute at Lehigh University showed that these properties vary as much within certain rolls as from roll to roll (*4*).

To average the test results of, say, five rolls out of a shipment in the measurement of quality is fairly typical. Essentially, an average of five press runs is not much different, except that five presses tend to produce a range of values for each mill that is wider than that of one press, and of most testing devices.

To learn if fewer runs would have given the same findings, the coefficients for all double, triple, and quadruple runs were also calculated. There are five possible combinations of four runs each from the data in Table I: runs 1, 2, 3, and 4; runs 1, 2, 3, and 5; runs 1, 2, 4, and 5; runs 1, 3, 4, and 5; and runs 2, 3, 4, and 5; In the same order, the coefficients for the means of four were: 0.658, 0.962, 0.926, 0.886, and 0.941. Had the trial stopped after the first four runs, the value of 0.658 would have been the not entirely happy result. The intuition to average five runs for these nearly alike papers was not overly generous.

### *Pressure Variation*

The decision to make wedge prints at five pressure levels, block height from 0.918 in. through 0.922 in., also was arbitrary.

Would Fewer Levels Have Sufficed? Thirty-one possible combinations of pressure levels can be calculated from the original five: a single pressure at each height, or five; ten possible averages of two pressures; ten possible averages of three pressures; five possible quadruple pressures; and one average of the five. The 31 coefficients of correlation against the master press run are best described graphically (Fig. 17). It would appear that any three pressure levels on five roll samples per mill give coefficients of the order of 0.9 or

better—and might prove sufficient for most general purposes.

Was There a Need to Include Any Pressure Variation? To learn if one print at each of five pressures (as we did) gave results significantly different from five prints at one pressure, an analysis of variance was performed (*5*). By the method known as "doubly incomplete three factor analysis: one factor with double order replication," one can analyze for (1) the main factor of variance between mills; (2) the replication variance between rolls within mills; (3) the replication variance between pressures within rolls.

The results were: (1) a highly significant difference between mills; probability 0.001; (2) a highly significant difference between the rolls within mills (*sic*); probability 0.001; and (3) *no* significant difference between wedge pressures within rolls. The implication from item 3 is that any single pressure could have been employed without altering the findings. Apparently, the relative ranking of the five mills must have remained approximately parallel as the pressure was raised.

The authors caution, however, that the same need not be true for all mills, and wish to provide an illustration of wedge test inversion (Fig. 18). Remember, it need be no more arduous to make a single print at each of several pressures than to make several prints at one pressure, and this would serve to guard against any inversions.

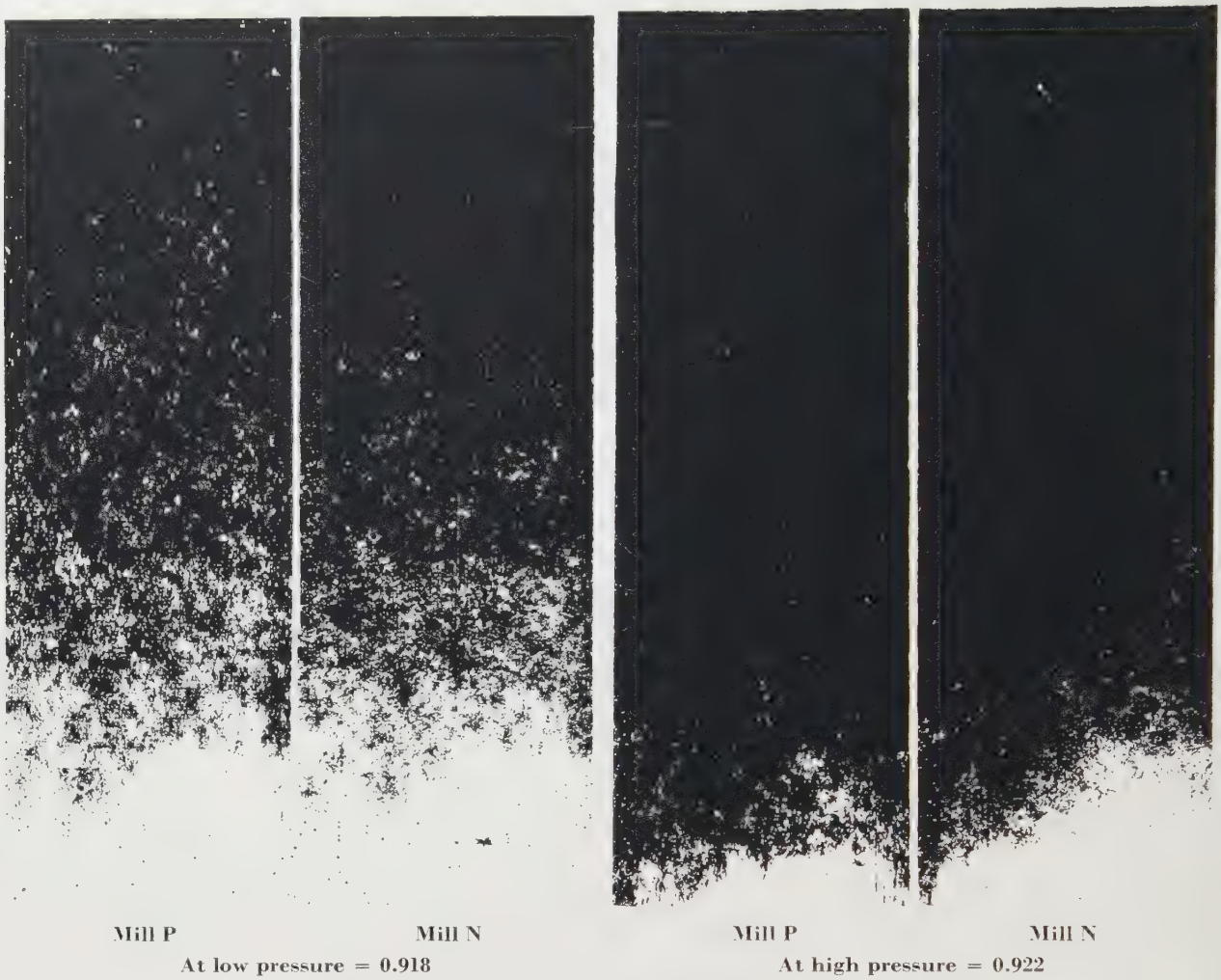
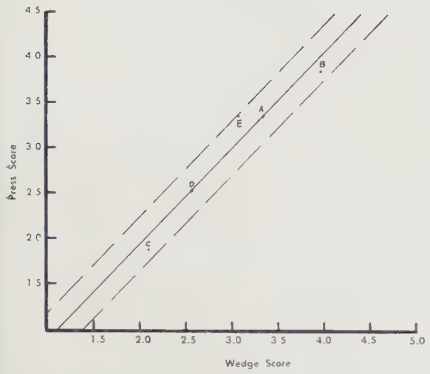


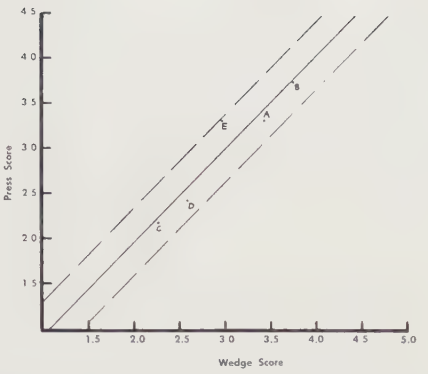

*Fig. 18. A pressure change may produce an inversion in ranking; see Fig. 9*

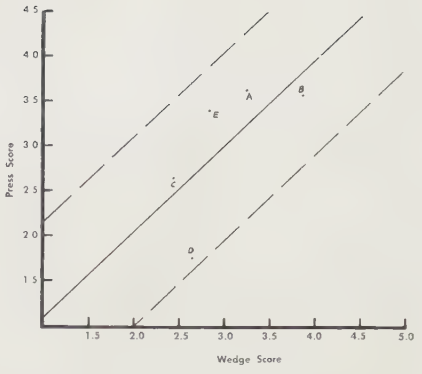
Up to this point, only data of subpanel 1 have been treated. The other subpanels shared their experience, namely, poor agreement between individual runs, and relatively good correlation of the mean (Table II). Again, the rankings are shown in the last two columns. The chi-square-r and concordance values show excellent agreement between the panels. This is fairly remarkable when one considers how nearly alike the papers were, how the methods and degrees of training of judges might have varied, that none of the judges in subpanels 1 to 5 had ever before compared wedge prints, and that almost no instructions were given. Note that the untrained subpanel 6 ranked the press prints differently from the others—only 6 did not judge mill B the worst, etc.—but agreed very well with the others on the wedge prints. Little training appears to be needed by a prospective judge of wedge prints, but the converse may be true for press prints.

The mean press score is an average of 15 press print comparisons per judge, while the wedge score is an average of 25. The correlation coefficients are pleasingly good. To help visualize the relative precision of this data, graphs were prepared for subpanel 1, the grand panel, and subpanel 6 (Figs. 19, 20, and 21.)

The unbroken central line is the regression—the line of best fit—of the press score on the wedge score. In these regressions, and all those which follow, two-sigma limits (two standard deviations) are indicated by the




**Wire side regressions of press score on wedge score:**

***Fig. 19. Subpanel 1; coefficient 0.976*** ***Fig. 20. Grand panel; coefficient 0.949*** ***Fig. 21. Subpanel 6; coefficient 0.677***

dotted lines above and below the central line. The position of the limits are, in part, a function of the correlation coefficient; the larger the coefficient, the narrower the limits *tend* to be.

Compare subpanel 1 and the grand panel: both arranged the mills in the same order, but the spread between best and poorest is slightly more for subpanel 1, which perceived greater distinction. Also, both intercepts are nearly identical; the slopes of both are slightly more than 45°; etc.

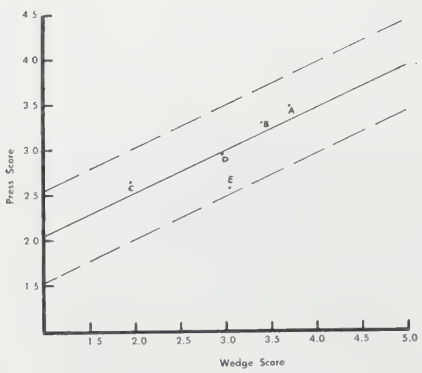
The line for subpanel 6 slopes at an angle of slightly less than 45°, and its intercept is no further removed from the origin than the others. Observe that the order of arrangement of the mills is no longer the same, and the limits are wider partly due to the relatively small coefficient. Also, if one would seek to predict one score from that of the other, there is a much larger margin of uncertainty in this case.

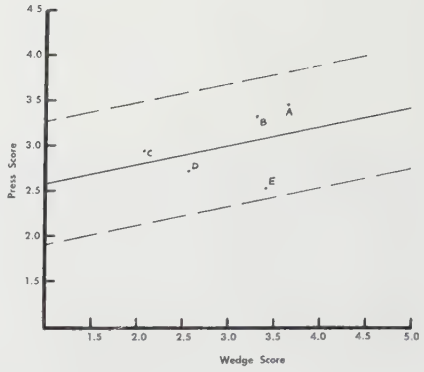
### *Analysis of Felt Sides*

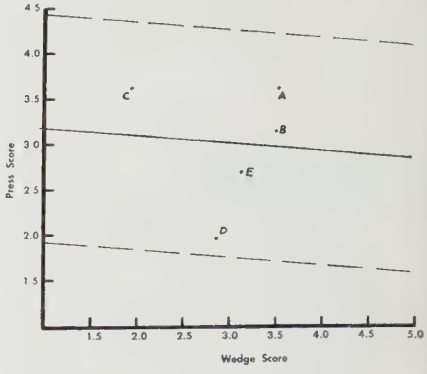
Some investigators limit testing to the wire side on the assumption that paper is as bad as its poorer printing side, which does not allow that it might sometimes be the felt which is the poorer. Also, if papers have equal wire sides and unequal felts, those with the better felt side might be preferred.

**Table III. Felt Side Correlations—All Panels**

| *Panel no.* | *No. of judges* | *Mill* | *Mean score* — *Press* | *Mean score* — *Wedge* | *Correlation coeff.* | *Ranking* — *Press* | *Ranking* — *Wedge* |
|---|---|---|---|---|---|---|---|
| 1 | 4 | A | 3.489 | 3.700 | | 5 | 5 |
| | | B | 3.311 | 3.380 | | 4 | 4 |
| Most highly skilled; regular comparison of all types of printing | | C | 2.644 | 1.940 | | 2 | 1 |
| | | D | 2.978 | 2.950 | | 3 | 2 |
| | | E | 2.578 | 3.030 | 0.777 | 1 | 3 |
| 2 | 1 | A | 3.233 | 3.660 | | 4 | 5 |
| | | B | 3.467 | 3.020 | | 5 | 3 |
| Skilled in judging; largely, solids | | C | 2.533 | 1.900 | | 1 | 1 |
| | | D | 2.967 | 2.820 | | 3 | 2 |
| | | E | 2.800 | 3.600 | 0.605 | 2 | 4 |
| 3 | 3 | A | 3.489 | 3.613 | | 5 | 5 |
| | | B | 3.333 | 3.440 | | 4 | 4 |
| Mixed panel; one judge skilled, two trained very briefly | | C | 3.067 | 2.267 | | 3 | 1 |
| | | D | 2.511 | 2.680 | | 1 | 2 |
| | | E | 2.600 | 3.000 | 0.580 | 2 | 3 |
| 4 | 6 | A | 3.589 | 3.681 | | 5 | 4 |
| | | B | 3.300 | 3.313 | | 4 | 3 |
| Paper chemists with some judging experience, mainly, solids | | C | 3.056 | 2.113 | | 3 | 1 |
| | | D | 2.644 | 2.120 | | 2 | 2 |
| | | E | 2.411 | 3.773 | 0.192 | 1 | 5 |
| 5 | 3 | A | 3.259 | 3.534 | | 4 | 4 |
| | | B | 3.333 | 3.193 | | 5 | 3 |
| Skilled in examination roto print test proofs; semiskilled letterpress | | C | 3.050 | 1.993 | | 3 | 1 |
| | | D | 2.800 | 2.707 | | 2 | 2 |
| | | E | 2.558 | 3.573 | −0.180 | 1 | 5 |
| Grand Panel | 17 | A | 3.455 | 3.646 | | ΣA 23 | ΣA 23 |
| | | B | 3.326 | 3.313 | | ΣB 22 | ΣB 17 |
| The five panels above are treated as a single, large panel | | C | 2.953 | 2.066 | | ΣC 12 | ΣC 5 |
| | | D | 2.735 | 2.559 | | ΣD 11 | ΣD 10 |
| | | E | 2.531 | 3.416 | 0.351 | ΣE 7 | ΣE 20 |
| Statistical calculations of agreement between panels: $x^2r$ = probability of rank sums by chance, 1 in— $W$ = coefficient of concordance (perfect = 1.0) | | | | | | 345 0.808 | 625 0.872 |
| 6 | 3 | A | 3.600 | 3.533 | | 4 | 5 |
| | | B | 3.133 | 3.520 | | 3 | 4 |
| Almost no judging experience; no training; no instructions | | C | 3.622 | 1.947 | | 5 | 1 |
| | | D | 1.956 | 2.853 | | 1 | 2 |
| | | E | 2.689 | 3.147 | −0.087 | 2 | 3 |




**Felt side regressions of press score on wedge score:**

*Fig. 22. Subpanel 1; coefficient 0.777* *Fig. 23. Grand panel; coefficient 0.351* *Fig. 24. Subpanel 6; coefficient −0.087*

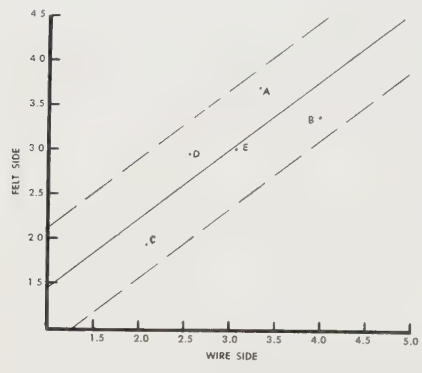
Table III is the felt side counterpart of Table II. Chi-square-r and concordance values for the wedge test are much better than those for the press runs. Compared to the values of the wire sides, these are only fair. The coefficients range from fair (for subpanel 1) down to very poor, and the relative precision of the data is better visualized from the graphs (Figs. 22, 23, and 24).

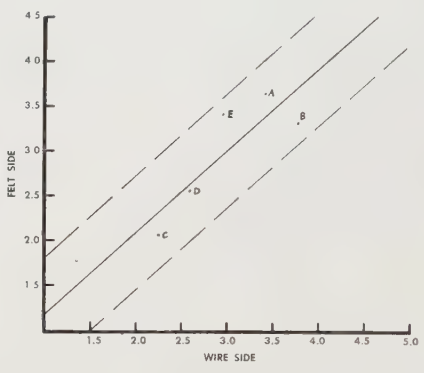
None of the slopes is close to 45°. The intercept of subpanel 1 comes closest to the origin. The orders of actual difference between papers. It has been shown a reliable resolution of the wire sides. Five runs appear to have been too few for the felt sides.

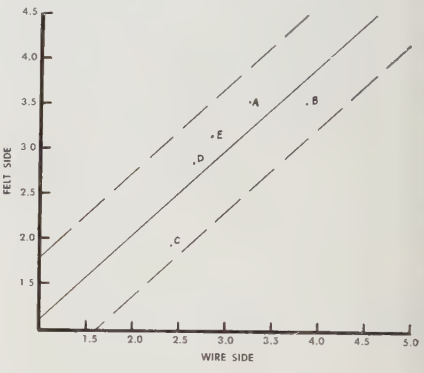
For subpanel 6 and the grand panel, there is much too large a margin of uncertainty to allow predictions of press scores from the wedge; that of subpanel 1 is somewhat better.

### *Analysis of Felt Sides Versus Wire Sides*

There is generally a loose parallel in the qualities of



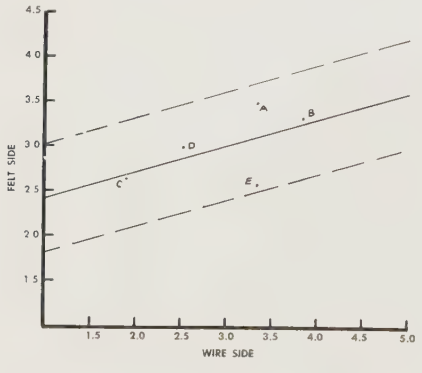



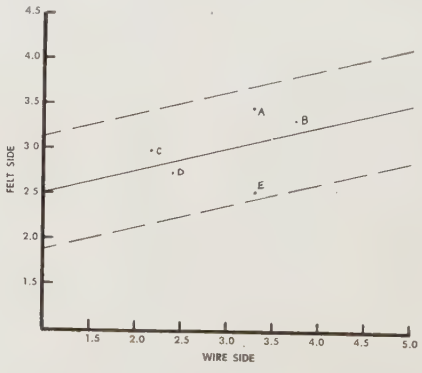

**Wedge test only, the regressions of felt side on wire side:**

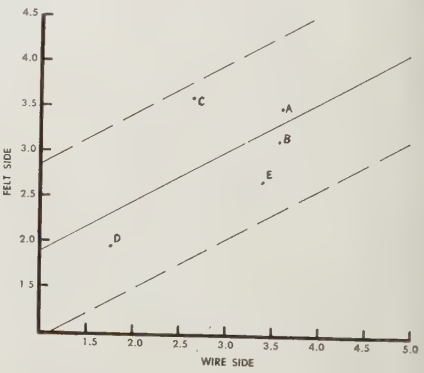
*Fig. 25. Subpanel 1; coefficient 0.835* *Fig. 26. Grand panel; coefficient 0.845* *Fig. 27. Subpanel 6; coefficient 0.814*

arrangement by the three groups now differ a little that the mean of five press runs was barely sufficient for more. The spread between best and poorest is less than for the corresponding wire sides; the inference is that there is less difference between the felt sides than the wire sides. Within-mill variations, the difference between runs, the lack of experience of some judges (?), etc., may be more nearly of the same magnitude as the both sides of papers. The factors contributing to the quality of one side may do the same for the other. But a ratio of quality need not be constant within one mill, much less across mills. Although there is a fair parallelism between sides for these five mills, it need not be typical of others.

Figures 25, 26, and 27 describe the wedge regressions, wire versus felt, for our three panels. All rank wire

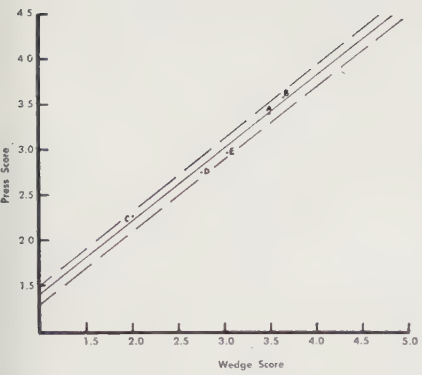


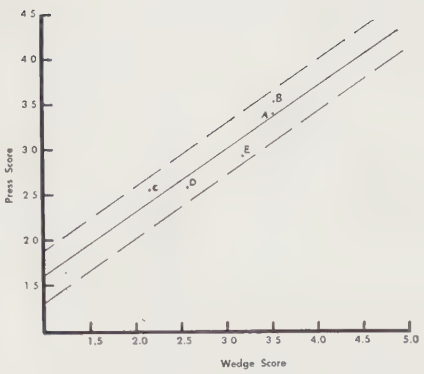



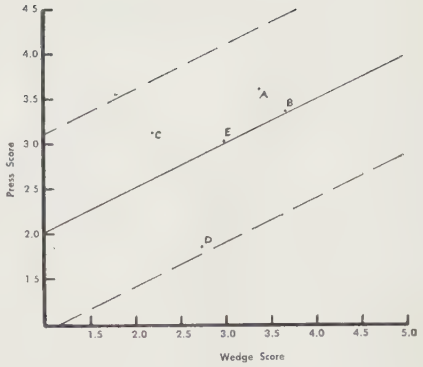




**Master press run only, the regressions of felt side on wire side:**

*Fig. 28. Subpanel 1; coefficient 0.557* *Fig. 29. Grand panel; coefficient 0.415* *Fig. 30. Subpanel 6; coefficient 0.628*




**Mean of both sides, the regressions of press score on wedge score:**

*Fig. 31. Subpanel 1; coefficient 0.994* *Fig. 32. Grand panel; coefficient 0.934* *Fig. 33. Subpanel 6; coefficient 0.421*

sides in the same order; all rank mill C as the best felt side, and mill A equal to or the poorest. All correlation coefficients are better than 0.8.

The press judgments seem to be less facile (Figs. 28, 29, and 30). Subpanel 6 has a different order of arrangement than subpanel 1 and the grand panel.

In all six graphs, there is quite a large margin of uncertainty if one wishes to predict quality of one side from that of the order.

### *Analysis of the Mean of Both Sides*

A mean number is abstract except when both sides are equal. Also, an infinite number of combinations give the same mean. It is often useful, however, to know the mean plus or minus half the difference between sides.

Since 15 press and 25 wedge prints were averaged for each side, the mean of both sides averages 30 and 50 prints, respectively. This is not the same as taking a mean wire (or felt) judgment across 10 runs. If the wire side judgment is closer to the truth than that of the felt side, splitting the difference may reduce the standard error of slope of the felt line, but it is at the expense of the wire line. The predicting quality of a graph of the mean of both sides shows less uncertainty as the slopes of the wire and felt lines approach one another, and more uncertainty as they diverge.

The graphs for the mean of both sides for the three

**Table IV. Correlations of Mean of Felt and Wire—All Panels**

| *Panel no.* | *No. of judges* | *Mill* | *Mean score* Press | *Mean score* Wedge | *Correlation coeff.* | *Ranking* Press | *Ranking* Wedge |
|---|---|---|---|---|---|---|---|
| 1 | 4 | A | 3.422 | 3.515 | | 4 | 4 |
| | | B | 3.589 | 3.670 | | 5 | 5 |
| Most highly skilled; regular comparison of all types of printing | | C | 2.267 | 2.010 | | 1 | 1 |
| | | D | 2.755 | 2.755 | | 2 | 2 |
| | | E | 2.967 | 3.050 | 0.994 | 3 | 3 |
| 2 | 1 | A | 3.217 | 3.350 | | 4 | 3 |
| | | B | 3.683 | 3.360 | | 5 | 4 |
| Skilled in judging; largely, solids | | C | 2.233 | 2.130 | | 1 | 1 |
| | | D | 2.767 | 2.700 | | 2 | 2 |
| | | E | 3.100 | 3.460 | 0.894 | 3 | 5 |
| 3 | 3 | A | 3.389 | 3.587 | | 4 | 4 |
| | | B | 3.489 | 3.593 | | 5 | 5 |
| Mixed panel; one judge skilled, two trained very briefly | | C | 2.811 | 2.267 | | 2 | 1 |
| | | D | 2.378 | 2.647 | | 1 | 2 |
| | | E | 2.933 | 2.906 | 0.835 | 3 | 3 |
| 4 | 6 | A | 3.445 | 3.627 | | 4 | 5 |
| | | B | 3.506 | 3.480 | | 5 | 4 |
| Paper chemists with some judging experience, mainly solids | | C | 2.594 | 2.253 | | 1 | 1 |
| | | D | 2.611 | 2.347 | | 2 | 2 |
| | | E | 2.844 | 3.293 | 0.919 | 3 | 3 |
| 5 | 3 | A | 3.325 | 3.390 | | 4 | 4 |
| | | B | 3.558 | 3.540 | | 5 | 5 |
| Skilled in examination roto print test proofs; semiskilled letterpress | | C | 2.642 | 2.073 | | 2 | 1 |
| | | D | 2.496 | 2.650 | | 1 | 2 |
| | | E | 2.979 | 3.347 | 0.835 | 3 | 3 |
| GRAND PANEL | 17 | A | 3.389 | 3.535 | | ΣA 20 | ΣA 20 |
| | | B | 3.541 | 3.549 | | ΣB 25 | ΣB 23 |
| The five panels above are treated as a single, large panel. | | C | 2.565 | 2.159 | | ΣC 7 | ΣC 5 |
| | | D | 2.577 | 2.570 | | ΣD 8 | ΣD 10 |
| | | E | 2.928 | 3.187 | 0.934 | ΣE 15 | ΣE 17 |
| Statistical calculations of agreement between panels: $\chi^2 r$ = probability of rank sums by chance, 1 in— $W$ = coefficient of concordance (perfect = 1.0) | | | | | | 1000+ 0.952 | 625 0.872 |
| 6 | 3 | A | 3.611 | 3.387 | | 5 | 4 |
| | | B | 3.356 | 3.693 | | 4 | 5 |
| Almost no judging experience; no training; no instructions | | C | 3.133 | 2.186 | | 3 | 1 |
| | | D | 1.856 | 2.747 | | 1 | 2 |
| | | E | 3.044 | 2.987 | 0.421 | 2 | 3 |

**Table V. The Comparison of Thirteen Tests Against Master Press Run Rating by the Three Panels**

| | *Press judgment by subpanel 1* | | | *Press judgment by grand panel* | | | *Press judgment by subpanel 6* | | |
|---|---|---|---|---|---|---|---|---|---|
| | *Wire* | *Felt* | *Wire and felt mean* | *Wire* | *Felt* | *Wire and felt mean* | *Wire* | *Felt* | *Wire and felt mean* |
| Ink strike-in[a] | 0.845 | 0.255 | 0.721 | 0.819 | −0.0036 | 0.606 | 0.630 | −0.154 | 0.293 |
| E test[b] | 0.838 | 0.597 | 0.976 | 0.897 | 0.360 | 0.964 | 0.938 | −0.218 | 0.525 |
| Bendtsen "hardness"[b] | 0.771 | −0.170 | 0.480 | 0.849 | 0.134 | 0.627 | 0.925 | 0.639 | 0.793 |
| Rotogravure print test[a] | 0.654 | −0.127 | 0.583 | 0.683 | 0.466 | 0.513 | 0.492 | −0.690 | 0.0726 |
| Chandler & Price letterpress[a] | 0.466 | 0.662 | 0.886 | 0.576 | 0.215 | 0.925 | 0.861 | −0.524 | 0.673 |
| H test[b] | 0.434 | 0.457 | 0.208 | 0.386 | 0.522 | 0.199 | 0.0687 | 0.0811 | −0.130 |
| PATRA oil test[b] | 0.350 | −0.483 | 0.094 | 0.422 | −0.536 | 0.088 | 0.621 | −0.115 | 0.262 |
| Bendtsen smoothness[b] | −0.034 | 0.238 | 0.103 | −0.146 | −0.118 | −0.100 | −0.576 | −0.788 | −0.705 |
| Bekk smoothness[a] | 0.0742 | −0.395 | −0.030 | 0.129 | −0.241 | −0.060 | 0.362 | 0.389 | 0.129 |
| Chapman, glass backing[c] | −0.921 | −0.120 | −0.728 | −0.865 | 0.093 | −0.585 | −0.452 | 0.356 | −0.097 |
| Bausch & Lomb opacity[a] | −0.406 | −0.0438 | −0.316 | −0.491 | −0.0122 | −0.419 | −0.777 | −0.492 | −0.717 |
| Ingersoll glarimeter[a] | −0.342 | 0.413 | −0.284 | −0.274 | 0.443 | −0.198 | 0.135 | 0.301 | 0.202 |
| Chapman, rubber backing[c] | 0.170 | 0.647 | 0.158 | −0.171 | 0.575 | 0.172 | 0.0308 | 0.335 | 0.241 |

[a] Kimberly-Clark Corp.
[b] Central Laboratory of the Finnish Industries, Dept. for Paper Research.
[c] Institute of Paper Chemistry; tests at 354 p.s.i.
*Note:* The larger the press score, the poorer the print quality. The same is supposedly true for the scores of the top eight tests, which should make their coefficients positive to show agreement. On the other hand, the lower five should be negative.

panels are shown in Figs. 31, 32, and 33, and visually indicate the relative precision of the data. The predictability from that of subpanel 1 is very superior; that of the grand panel is good; that of subpanel 6 is very uncertain.

Table IV lists the data for all panels. The agreement between panels was very good. The small range between the best and the poorest mean scores of both press and wedge again accent how nearly alike the five mills are.

### *Analysis of the Master Press Run Against Other Tests*

The study was extended to learn the value of other tests in predicting print quality. The presentation of all data and graphs for 13 additional tests would be formidable. Instead, and by way of summarizing, Table V lists the correlation coefficients for the felt, wire, and mean of both sides of each test against the master press run judgment by our three panels—highly trained, average, and untrained. (Data supplied on request.)

*For these five mills,* there is an absence of correlation against the Bekk and Bendtsen smoothness tests. This does *not* indicate that smoothness plays no role in print quality. Repeated press room observations have shown excellent parallelism between smoothness and print quality within one mill, and particularly on paper from one machine. It is entirely possible that there may be good intramill correlation, while intermill correlation may be poor.

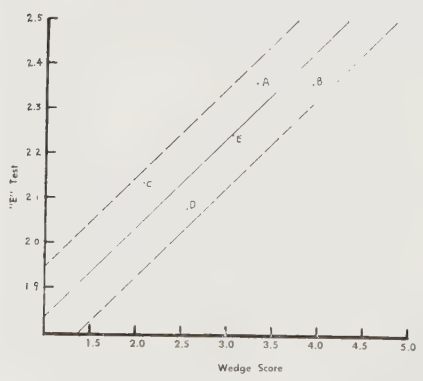
The Chapman test (*6*) appears to show much better agreement with the master press run when performed with a glass backing than with a rubber backing.

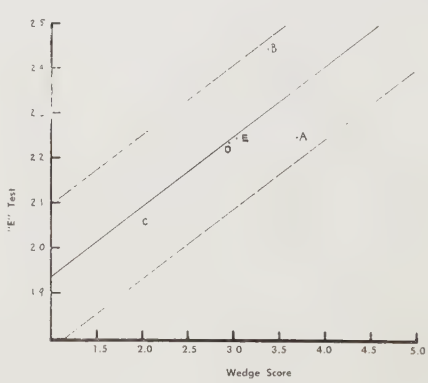
Kimberly-Clark's ink strike-in test shows interesting agreement with the master press run. (It is a measure of the depth of penetration of standard inks into papers, and combines controlled proof press techniques with optical measurements of the *reverse* side.)

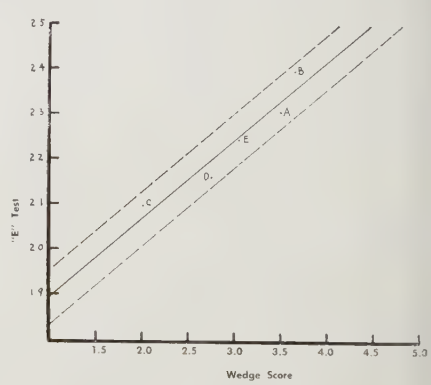
Two controlled proof press tests, Rotogravure and Chandler & Price, both of which rate proofs against sets of standards, show fair agreement.

Attention is directed to Ginman's E test (*7*) shown in Fig. 37. Briefly, a plate is inked and printed at fixed pressure with successively increasing amounts of ink. As the ink film increases, but still in the thin film area, the per cent that transfers to the paper approaches, equals, then exceeds 50% of the ink originally present on the printing plate. The E value is the parameter describing the weight (grams per square meter) on the plate at which 50% transfer occurs. Although it is sometimes necessary to interpolate, the average of several samples can provide a reasonably precise number. The procedure, however, may be said to be cumbersome. The angle of intersection between the curve and the 50% transfer line is sometimes small. (The choice of exactly 50% can be said to have been arbitrary and makes one wonder if lower or higher percentages or another pressure might not give even better correlation.)

Although wedge prints can be graded against stand-




**Regressions of E test on wedge score, subpanel 1 only:**

*Fig. 34. Wire side coefficient 0.862*

*Fig. 35. Felt side coefficient 0.764*

*Fig. 36. Mean of both sides coefficient 0.959*

rds, their replacement, or duplication by others, might be difficult. If the value of a standard can be fixed by another test which provides an exact number, then replacement and duplication is simple. The authors had little success with reflectance measurements, but the E test appears to be promising.

Regressions of E against wedge are shown for subpanel 1 only in Figs. 34, 35, and 36. The three slopes are nearly alike, and the five mills easily contained within two-sigma limits. The relationship appears to be valid but should be confirmed by making a comparison of, say, ten papers.

Both tests involve printing with varying ink film thicknesses. True, the wedge employed varying pressures while the E did not, but the analysis of variance showed the variation to have been superfluous *for these five mills.*

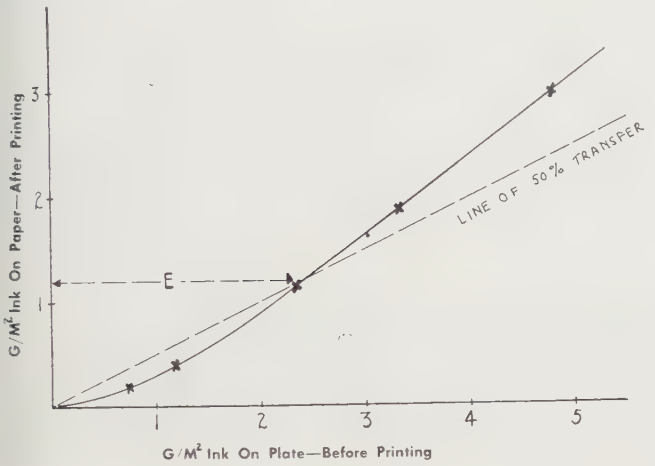



***Fig. 37. Ginman's E Test—50% transfer occurs in the thin film areas***

Extensive studies of ink transfer phenomena have also been made by the Swedish Graphic Arts Research Laboratory (*8*), the Institute of Paper Chemistry in collaboration with ANPA (*9*), and the NPIRI (*10*). The last group, plotting per cent transfer against grams ink on the printing ppate show a maximum for each paper-ink couple in the thin film area (Fig. 38).

Ink transfer studies appear to promise hope for a definitive means of predicting print quality of paper, ink, and their combination. Through this study, a blue-sky ink transfer test, E, has been shown to give good agreement with newspaper production runs, and that is a most interesting association.

## SUMMARY AND CONCLUSIONS

Any test method which can measure and predict print quality under normal commercial printing conditions can be very useful. Unless such a test is used, the printing production man may be hard put to fix the blame for bad printing, and the papermaker to effect improvements. If a test is represented to have this ability, it should be proved against normal practice. Since single runs can yield a wide range of results, even when performed on "duplicate" rolls, the authors prefer averaging a number of runs. Although this is arduous, it is also necessary for the validation of a test. Once proved, however, a simplified version may suffice.

To illustrate, use *three* blocks like that in Fig. 11, except that they need be only single channel. The heights of the printing surfaces can be 0.918, 0.920, and 0.922 in. to give the pressure variation. Print the sample across the three blocks at one time. Take interior paper samples of at least five rolls per mill; this means only five proving operations per mill. Compare against other mills or standards. Although the pressure variation was found to be unnecessary for the five papers tested, its inclusion is recommended to guard against possible inversions.

The "master press run" was simply the application of a Latin square design to five uncontrolled press runs. Five runs were barely sufficient for the nearly alike wire sides, and insufficient for the felt which were even more nearly alike. Six subpanels of from one to six judges,

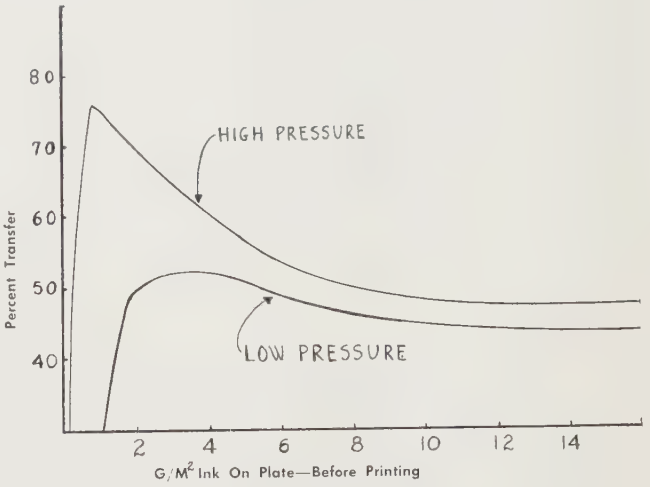



***Fig. 38. When the pressure is raised, the largest increase of ink transfer occurs in the thin film region (Fetsko & Walker)***

and covering the entire range of experience, ranked both wedge and press prints visually. Little training seems necessary for a good wedge print ranking, but the more experienced judges appeared to perform better with the press prints. The authors recommend that judges have considerable "self-training" and suggest that they should not be chosen from production staffs. Small samples, covering a wide range of tones and solids, were used in the comparison.

The wire side correlation of wedge against the master press run gave a coefficient of 0.976 for the most highly trained subpanel. Assuming only three degrees of freedom (not four) for five papers, the probability for this coefficient is between 0.01 and 0.001. The same subpanel had a coefficient of 0.994 for the mean of both sides, the corresponding probability for which is 0.001. The analysis of the felt sides was much less satisfactory, probably arising, in a large measure, from the unsure judgment by some of the press prints. The same subpanel yielded the best coefficient 0.777.

There was fair correlation between wire and felt sides for these papers.

Thirteen additional tests were correlated against the master press run. No correlations against Bendtsen and Bekk smoothnesses were apparent. Chapman smoothness with glass backing agreed very well on the wire side, but not at all well on the felt. The E test of the Finnish Pulp & Paper Research Institute appears to

indicate that further study into ink transfer phenomena may provide the real key to print quality evaluation.

The E test appears to correlate fairly well with the wedge test, but this needs to be confirmed. If found to be valid, it will provide the means for the establishment of precise wedge standards. In any event, arbitrary standards can be established.

Since this is the second wedge study by the authors, and the findings for both were alike, it is considered by them to offer a reliable means of predicting print quality in the New York *Times* press room. Another wedge study is now in progress. Also, investigators are invited to confirm these findings on other presses.

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# Sugar Units Percentage, Viscosity and Degree of Polymerization, Accessibility, and Other Data on the ICCA "Standard" Pulps


RICHARD W. DETRICK



**Glucose, mannose, and xylose unit-percentages, sorption ratio, hydrolysis crystallinity, copper number, trinitrate intrinsic viscosity, and degree of polymerization data are presented in this paper as an aid in the characterization of the ICCA "standard" pulps. Also presented is a summary of the data available from the distributors of the pulps.**


Recently, a series of eight "standard" pulps has been selected by the International Committee for Cellulose Analysis (ICCA) for use by various analysts as an aid in evaluating their methods for characterizing cellulose. The pulps, numbered one through nine (no. 6 is no longer obtainable), were obtained from Buckeye Cellulose Corp., Memphis, Tenn. (nos. 1–5), and from Miss Karin Wilson, Skoghallsverken, Skoghall, Sweden (nos. 7–9).

Sugar unit percentages, viscosity and degree of polymerization, accessibility and other data are presented in this paper as an aid in characterizing these pulps. Also presented are data available from the distributors of the pulps.


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## EXPERIMENTAL

### *Sugar Units Contents*

The glucose, mannose, and xylose-unit contents were determined quantitatively by the chromatographic, spectrophotometric method, developed by Timell and co-workers (*1*), and modified by Piper and Bernardin (*2*). The pulps were hydrolyzed by the method of Saeman and collaborators (*3*). The factors given by Saeman to correct for the loss of sugars during hydrolysis were used in the analysis.

Sheets of Whatman no. 1 chromatographic paper were washed with distilled water in a chromatographic tank for two 20-hr. periods with *thorough* airdrying between washes. The washed sheets were spotted within a day after the final washing. The technique gave quite low "blank" optical densities. The developer was ethyl acetate:acetic acid:water, 9:2:2, v/v, and the spray reagent and eluent consisted of 1.0 g. purified *o*-aminobiphenyl, 40 ml. distilled water, and 210 ml. glacial acetic acid. Baker-analyzed, reagent-grade 99.8% glacial acetic acid was used for the developer and 99.9% acid for the spray reagent and eluent.

All sugars were spotted within the range of 20 to 100 $\gamma$. The optical densities of the solutions were read on a Beckman DR spectrophotometer at 380 $\mu$ with a slit

**Table I. Sugar Units Content of ICCA "Standard" Pulps**

| Pulp no. | Description of pulp | Total determined sugars, weight %: Glucose, % | Mannose, % | Xylose, % | Xylan, % C.C.A. 24:57[a] |
|---|---|---|---|---|---|
| 1 | Cotton linters | 99.5 | 0.0 | 0.5 | 0.4 |
| 2 | Sulfite pulp, acetate grade | 98.5 | 0.4 | 1.1 | 1.1 |
| 3 | Prehydrolyzed kraft pulp | 97.9 | 1.0 | 1.1 | 0.9 |
| 4 | Softwood sulfite pulp, rayon grade | 95.3 | 2.5 | 2.2 | 2.1 |
| 5 | Sulfite pulp, cellophane pulp | 96.1 | 2.5 | 1.4 | 1.4 |
| 7 | Sulfite pulp, paper grade | 87.9 | 7.5 | 4.6 | 4.6 |
| 8 | Sulfite pulp, greaseproof grade | 83.5 | 11.4 | 5.1 | 5.9 |
| 9 | Sulfite pulp, birch, rayon grade | 95.1 | 1.1 | 3.8 | 3.7 |

[a] Data obtained from distributors of pulps.

width of 0.08 mm. The determination, when applied to standard sugar solutions, gave coefficients of variation (*4*) for glucose, mannose, and xylose of 1.5, 2.0, and 2.0% respectively.

### *Accessibility*

Sorption ratios were determined by the method of Howsmon (*5*). The pulp samples were conditioned 114 hr. at 73° F. and 50% R.H.

The "hydrochloric acid-residue" or hydrolysis crystallinities were determined by the method of Philipp and co-workers (*6*). Samples consisting of 0.2 g. pulp were hydrolyzed various times, up to 30 hr., with 50 ml. of 4 *N* HCl at 100°C. After using Philipp's factors to correct for the formation of humic materials, the logarithm of percentage residue was extrapolated to zero time in order to obtain the crystallinity. The correction coefficients of all plots were 0.99.

### *Degree of Polymerization*

Cellulose nitrates were prepared by the method of Timell and Bennett (*7*). Viscosities were obtained using ethyl acetate as the solvent, at 25°C., in a Cannon-Fenske no. 50 straight-type viscometer. Nitrogen contents of the cellulose nitrates were determined by the Analytical Department of The Institute of Paper Chemistry using the modified Kjeldahl method of Timell and Purves (*8*). The intrinsic viscosities of the cellulose nitrates were converted to the trinitrate intrinsic viscosities by the use of the Lindsley and Frank equation (*9*).

The degree of polymerization was obtained from the trinitrate intrinsic viscosity by using the equations:

$$\text{D.P.} = 67.2\ [\eta]_T \qquad (1)$$

**Table II. Accessibility Data Concerning the ICCA "Standard" Pulps**

| Pulp no. | Sorption ratio[a] | Hydrolysis crystallinity, % |
|---|---|---|
| 1 | 1.00 | 94 |
| 2 | 1.14 | 94 |
| 3 | 1.32 | 86 |
| 4 | 1.18 | 95 |
| 5 | 1.15 | 93 |
| 7 | 1.37 | 86 |
| 8 | 1.35 | 86 |
| 9 | 1.16 | 95 |

[a] The sorption ratio may be defined as the moisture regain of the pulp sample divided by the moisture regain of pulp no. 1, cotton linters.

$$\text{D.P.}^{1.01} = 103.26[\eta]_T \qquad (2)$$

Equation 1 was derived by Newman, Loeb, and Conrad (*10*) by means of sedimentation velocity-diffusion measurements, and modified by Timell and Bennett (*7*) to correspond to the trinitrate viscosity. Equation 2 was obtained by Flory and collaborators (*11*) by means of light-scattering measurements, and modified by the author (R. W. D.), using the Lindsley and Frank equation (*9*), to correspond to the trinitrate.

Cupriethylenediamine intrinsic viscosity data were obtained from the distributors of the pulps and converted to D.P. using the formula derived by Immergut, Schurz, and Mark (*12*):

$$\text{D.P.}^{0.905} = 0.75\ [\eta] \qquad (3)$$

### *Copper Number*

Copper numbers were determined using the Hägglund modification of the TAPPI Standard procedure (*13*).

## DISCUSSION

From Table I, it is seen that the two independent methods for the determination of xylose are in fairly close agreement. The data also agree fairly well with the pentosan determinations of these pulps given by Morrow (*14*).

That a correlation between sorption ratio and hydrolysis crystallinity occurs is evidenced by the data in Table II. Mark (*15*) has stated that all accessibility methods, both chemical and physical, in both swelling and nonswelling media, rank various cellulose fibers in the same order.

When the intrinsic viscosities of the cellulose trinitrates were compared with the cupriethylenediamine intrinsic viscosities of the pulps, some discrepancies were observed (Table III). The "cupriethylenediamine D.P." data (equation 3) agree with the cuprammonium data given by Morrow (*14*). The cupriethylenediamine viscosity, an alkaline viscosity, is influenced greatly by the presence of alkali-sensitive groups, such as partially oxidized units (*16*). Deter-

**Table III. Viscosity and D.P. Data Concerning the ICCA "Standard" Pulps**

| Pulp no. | Intrinsic viscosity, dl./g. | Nitrogen % | Trinitrate intrinsic viscosity, dl./g. | Degree of polymerization: Equation (1) | Equation (2) | Equation (3) | Cupriethylenediamine intrinsic viscosity, cm.³/g.[a] | Copper number |
|---|---|---|---|---|---|---|---|---|
| 1 | 25.3 | 13.63 | 29.9 | 2009 | 2851 | 1889 | 1230 | 0.2 |
| 2 | 19.7 | 14.15 | 19.7 | 1324 | 1885 | 1354 | 910 | 0.2 |
| 3 | 13.7 | 14.03 | 14.2 | 954 | 1364 | 774 | 550 | 0.2 |
| 4 | 14.8 | 14.10 | 15.0 | 1008 | 1440 | 885 | 619 | 1.0 |
| 5 | 9.8 | 14.00 | 10.3 | 692 | 993 | 561 | 410 | 1.0 |
| 7 | 21.9 | 14.01 | 22.9 | 1539 | 2190 | 1321 | 890 | 0.6 |
| 8 | 27.2 | 13.94 | 29.1 | 1956 | 2775 | 1395 | 935 | 1.5 |
| 9 | 13.2 | 13.89 | 14.3 | 961 | 1374 | 768 | 545 | 1.1 |

[a] Data obtained from the distributors of the pulps; C.C.A. Method 28: 57 (*18*).

Table IV. Alkali-Resistant Cellulose, Data Concerning the ICCA Pulps[a]

| Pulp no. | Insoluble, alkali-resistant cellulose in 10% NaOH, %[a,b] | Insoluble, alkali-resistant cellulose in 18% NaOH, %[a,b] |
|---|---|---|
| 1 | 89.9 | 99.5 |
| 2 | 95.4 | 97.6 |
| 3 | 97.1 | 98.4 |
| 4 | 90.4 | 94.0 |
| 5 | 84.3 | 91.9 |
| 7 | 85.7 | 88.3 |
| 8 | 83.6 | 85.1 |
| 9 | 88.2 | 92.5 |

[a] Data obtained from the distributors of the pulps.
[b] C.C.A. Method 24: 57.

minations of the copper numbers of the unoxidized pulps indicated this; pulp nos. 1 and 8, for example, have about equal nitrate viscosities but quite different cupriethylenediamine intrinsic viscosities. In all probability, the oxidation level of pulp no. 8 is greater than pulp no. 1 (since the copper number of pulp no. 8 is greater than pulp no. 1). Pulp nos. 7 and 2, and 9 and 3 are other examples. Also, in a recent investigation, Ellefsen and Vardheim (*17*) have found that, due to cross-linking, trinitrate viscosities (in acetone) appear to be too high.

The disagreement between the D.P. values in equations 1 and 2 does not imply that either or both equations are wrong; it merely indicates that the viscosity data, being primary data, should be listed or that the equations used to calculate D.P.'s should be given.

Some of the data discussed were obtained directly from the distributors of the pulps. These data were xylan contents (Table I), cupriethylenediamine viscosities (Table III), and all of the data in Table IV.

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# Morphological Properties of Cotton and Wood Fibers

## *I: Cotton Linters*


K. A. JURBERGS



**Electron microscopic evidence is presented that the cellulose bundles form ridges on the surface of cotton linters and that the surface structure of these fibers is very similar to staple cotton. The structural surface changes have been followed after different purification processes, such as extractions of the raw linters and commercial pulping processes. Commercial pulping removes the primary wall. The fibers are mainly covered by the outside layer of the secondary wall. The fibrillar bundles in this layer have a wide helix angle (50 to 60°). The subsequent layers of the secondary wall have perfectly parallel aligned bundles of fibrils with a narrow helix angle (24 to 30°). Blending hydroxyethylated cotton linters with untreated fibers helps to overcome the inherent beating difficulties of the cotton linters. The added material reinforces not only the existing bonds but also forms new bonds among fibers and bundles of fibrils generated in the beating process. Electron microscopic evidence is presented about the structural differences between blue and yellow staining fibers with the Simons stain and also about structural changes on the surface of fibers treated with an enzyme solution.**



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Microscopy as a research tool in cellulose chemistry has a comparatively short history. The first attempts to use the microscope were concerned with obtaining information on the physical dimensions of the basic constituents of cellulosic raw material—the pulp fibers. Identification of the source of the raw material was the next step where the usefulness of a microscope was recognized. With the expansion of the pulp industry the aims of microscopic investigations were widened and higher goals were set. The structure of the pulp fibers was investigated and facts about the architecture of the plant cell-walls gradually discovered. The advanced knowledge of the morphology of the pulp fibers was useful not only in pulping but it was also beneficial to the different pulp conversion processes. Fiber microscopy emerged as a new branch of scientific endeavor among the other long established research facilities.

Fiber microscopy received a new impetus when the biologists learned to apply electron microscopy to their problems. Specimen preparation techniques were developed for biological objects, and the electron micro-

**Table I. Diameters of Cotton Linters (in Microns)**

| Sample | Diameter, μ | |
|---|---|---|
| | Major axis | Minor axis |
| First cuts, average | 23.0 | 8.7 |
| First cuts, Corinth | 23.5 | 7.5 |
| First cuts, California | 24.4 | 11.6 |
| Second cuts, average | 26.4 | 13.3 |

scope soon became an important tool for research workers in cellulose chemistry. Due to these efforts the knowledge about the morphology of pulp fibers was considerably expanded. Direct investigation became possible on many points of conjecture raised by the older microscopic methods. New facts were also gradually discovered and the basic structural elements of the fiber walls were ascertained. In this article the results from work carried out in these laboratories are discussed to add new facts and clarify certain aspects in morphology of cotton linters.

The short, fuzzy fibers remaining on the cotton seeds after removal of the cotton staple fibers have received surprisingly little attention in the morphological studies of pulp fibers in the past. A part of the neglect of cotton linters may be attributable to their lesser importance in technical utilization compared to the cotton staple fibers. Another important reason is the minuteness of these fibers. Their physical dimensions are very unfavorable for any advanced microscopic specimen preparations. The little information available on cotton linters very frequently is derived from investigations on staple fibers. It is generally assumed that both types of these fibers are more or less alike and the characteristics of the staple fibers could be directly attributed to the cotton linters of the same variety. This may or may not be true in every case. Nevertheless, the cotton linters have a technical importance of their own and are worthy of serious consideration in research programs.

## PROCEDURE

A one-step replication technique was employed for obtaining the electronmicrographs. The fibers, in the form of thin hand-sheets, were covered by an approximately 150 A thick layer of metallic chromium. The chromium layer was deposited on the fibers by evaporation in a high vacuum apparatus at an angle of 45°. The chromium served as a combined replication and shadowing medium. The replicas were removed from the fibers by embedding in a cellulose nitrate film made tacky by wetting with amyl acetate. After the film hardened, the fibers were mechanically stripped leaving the chromium replicas embedded. A carbon supporting membrane was deposited on the replicas by high vacuum evaporation. The cellulose nitrate film was dissolved after placing a selected area on a specimen grid. The final specimen consisted of a chromium replica supported by a thin carbon film. The electronmicrographs were taken at an original magnification of 3600×. The photographically reversed negatives were printed with a final magnification of 5900×.

## RESULTS AND DISCUSSION

Selected data from measurements of the physical dimensions of cotton linters may serve the purpose of characterization of the fibers in discussion. The average diameters obtained from several measurements

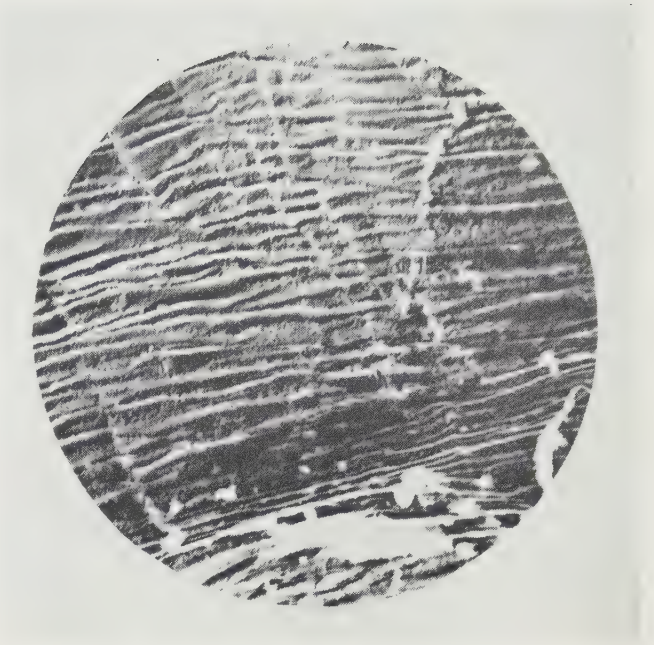

*Fig. 1. Electronmicrograph of a surface replica from a raw cotton linter (5900×)*

on cross sections of first and second cut cotton linters are summarized in Table I, including data from two geographic varieties.

The average length of second cut linters is from 2.0 to 2.5 mm. The length of first cut linters is usually from 2.5 mm. to about 6 mm., and shows a wide range of variation. The greater length of the first cut linters apparently depends on the amount of staple fibers present. The lengths of the cotton linters themselves are generally from 2 to 3 mm.

The most characteristic surface features found on cotton linters in electron microscopic investigations are ridges, or creases, running at an angle around the fiber. These ridges have approximately the same features and

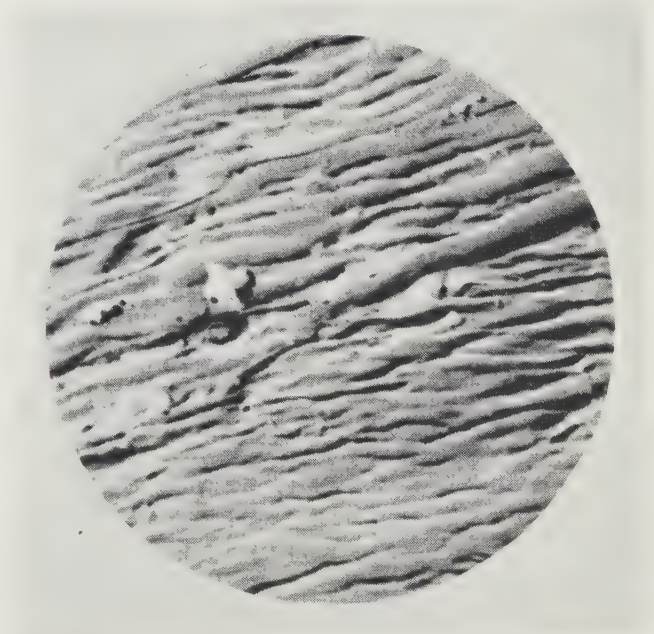

*Fig. 2. A surface replica from an alcohol-benzene extracted cotton linter (5900×)*

The swollen appearance of the ridges is the effect of solvent drying.

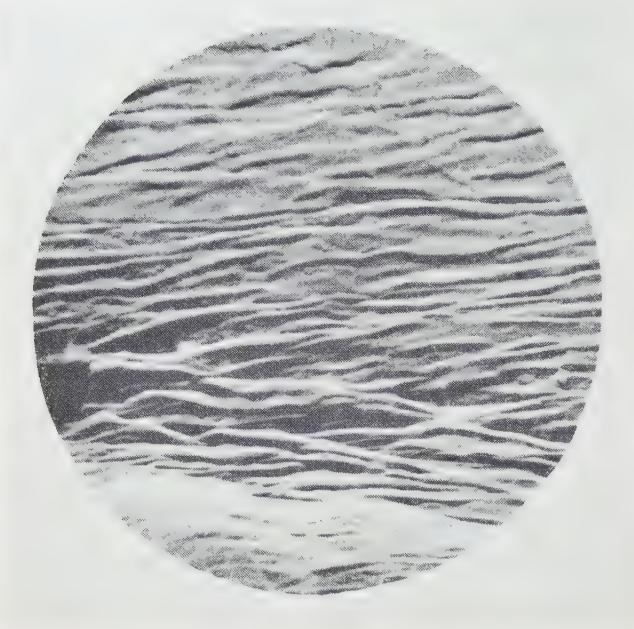

*Fig. 3. Surface replica of a cotton linter extracted with alcohol-benzene and subsequently with aqueous ammonium oxalate (5900×)*

dimensions as reported in the literature for cotton staple fibers (*1*). As seen in Fig. 1, on raw cotton linters the ridges are not very uniform over the whole surface of the fiber. In areas where they are more uniform they are spaced approximately 0.3 $\mu$ apart. Occasionally another system of ridges is discernible spaced further apart and having the appearance of folds. The fibrillar structure on the surface of a raw linters fiber is discernible. The fibrils, however, are never depicted very clearly and they seem to be masked by a structureless material, possibly waxes and pectic substances (*2*).

After the waxes are removed by extracting the fibers with alcohol-benzene the ridges are still visible on the

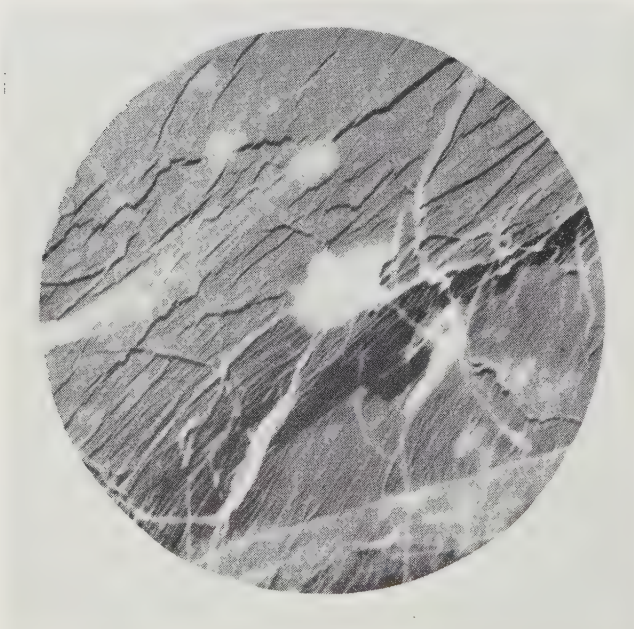

*Fig. 4. A surface replica of pulped and bleached cotton linter (5900×)*

The surface appears rather smooth without the characteristic ridges.

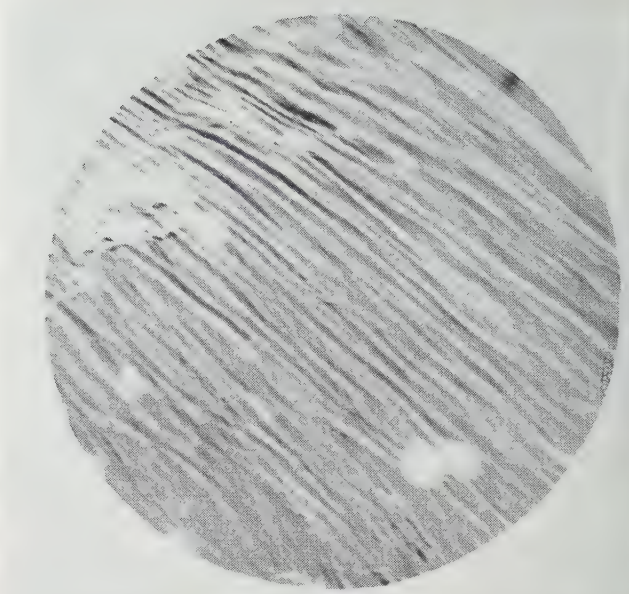

*Fig. 5. A purified cotton linter with the original ridges still present on the surface (5900×)*

fiber surface, as seen in Fig. 2. The surface has a swollen appearance and the ridges have become smoother and shallower. Further extraction with aqueous ammonium oxalate removes the pectic substances. In Fig. 3 such an extracted fiber has a surface structure similar to the structure of raw linters. Only the masking material has been removed and the ridges are very clearly defined. They do not have the swollen appearance, and the dimensions are the same as discerned on the raw fibers.

Summarizing the evidence obtained on the surface structure of cotton linters it must be concluded that it is very similar to the surface structure of staple cotton fibers. Since it is known (*1*) that cotton fibers from young unopened seed balls have a smooth surface, the

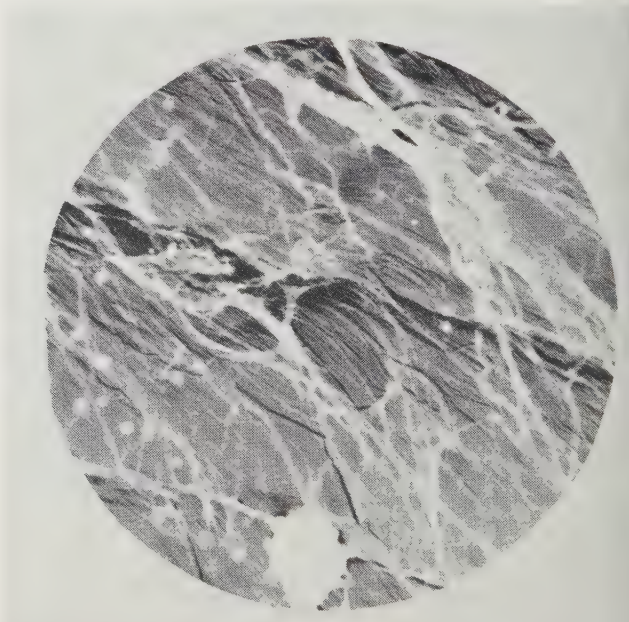

*Fig. 6. The surface replica of a pulped and bleached cotton staple fiber (5900×)*

The complete absence of the ridges is noticeable.

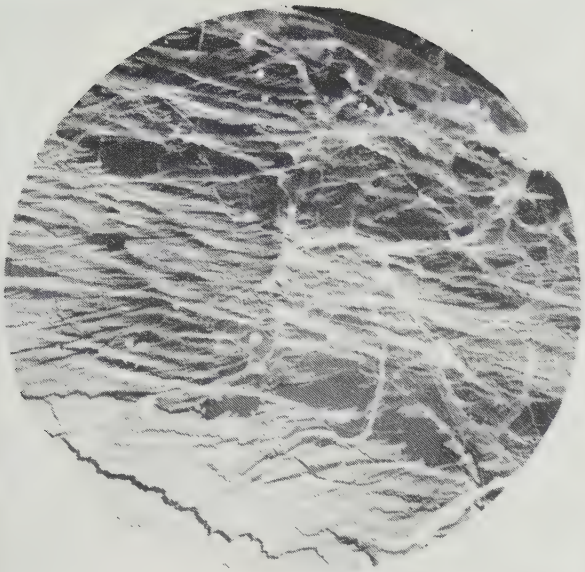

*Fig. 7. Another cotton staple fiber after purification (5900×)*

The original ridges are still discernible, although they are not so conspicuous, as frequently found on the cotton linters.

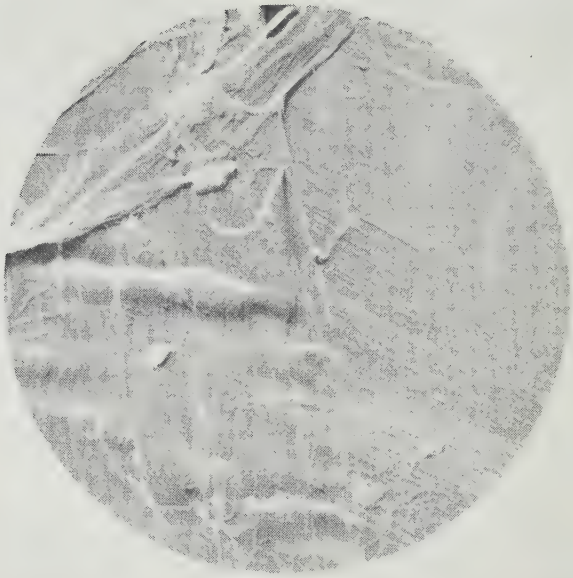

*Fig. 8. A surface replica of a cotton linter after 1 hr. beating in a Valley beater (5900×)*

A part of the loosened individual layer of the secondary wall is seen as thin membrane.

assumption seems to be justified that the ridges develop later in the growing season, very probably during the first drying after cessation of growth and development. The observed swollen appearance of the surface structure has some interesting implications. The phenomenon apparently is the effect of solvent drying. That means that in the presence of water the structural elements of the fiber walls can be brought close together by formation of hydrogen bridges even if the drying has not been preceded by an extensive purification. This might be an inherent characteristic of the cotton fibers where the impurities are at a low level originally.

The surface structure of cotton linters fibers is further influenced strongly during commercial pulping processes. Chemical and mechanical processes participate in creating changes in the structure of the fibers. Frequently, a rather smooth surface is observed on pulped linters, Fig. 4, and on staple fibers, Fig. 6. The smoothness seems to be more pronounced on the staple fibers. Although many manifestations of the presence of ridges can still be found on both linters (Fig. 5) and staple fibers (Fig. 7), their presence is more noticeable, and they are more pronounced on the surface of the linters.

After examination of a large number of electronmicrographs the conclusion can be drawn that, as a general rule, the primary wall is removed during pulping from all cotton fibers. A considerable amount of loose bundles and entanglements of fibrils is found on the surface of the fibers. Undoubtedly, there are remains of the primary wall among these bundled fibrils. A part of these bundles, however, originates also from the secondary wall.

The fibrils in the multilayered secondary wall form helices around the fiber axis (*3, 4, 5*). The helix angle (the angle between the tangent of the fibrillar bundles and the fiber axis) apparently varies to a great extent (*6*). The outside layer of the secondary wall, the first layer laid down on the inside of the primary wall upon initiation of the secondary thickening, differs considerably in structure from the rest of the secondary wall (*4, 7, 8*). This layer has been frequently called the winding layer. Since the fibrils in all of the layers of the secondary wall form spirals, the nomenclature does not seem to be completely justified. The fibrils in this layer are more transversally wound around the fiber axis. Measurements from our electron micrographs clearly indicate that two systems of fibrils can be found on the surface of cotton fibers. One system of the fibrils has a helix angle from 28 to 30°, the other an angle of about 60°. Since only a small number of the electronmicrographs were available for such measurements, and only very small areas of the fiber sur-

*Fig. 9. The fibrillar entanglement between two adjacent fibers after 2½ hr. beating in a Valley beater (5900×)*

face are involved in each case, any generalizations from these observations have of necessity to be limited and advanced with caution. However, light microscopy observations tend to support these measurements from the electronmicrographs. Measurements on surface replicas of two geographic varieties of purified cotton linters (South Carolina and California) revealed two systems of fibrils on the surface of these fibers. One of the systems had a helix angle around an average value of 24°, the other system from 50 to 60°. The conclusion from these observations seems to be warranted that the wider fibrillar angle belongs to the outermost layer of the secondary wall. The steeper helix angle would be found in the deeper layers of the secondary wall. Such an assumption is also substantiated by the electron microscopic observations that pulping frequently removes the outer layer of the secondary wall partially along with the primary wall. In these cases the highly parallel arranged bundles from the inside layers are clearly discernible covering the surface areas of the fibers in these places.

The shortage of cotton rags due to the increased use of synthetic fibers in textiles has necessitated an increased consumption of cotton linters in the paper industry. However, the difficulties encountered in beating of cotton linters are very well known. The study of beating of cotton linters and its related processes therefore has become of paramount interest. As would be expected, beating has a very strong influence on the fiber surface. A moderate beating frequently loosens the individual layers of the secondary wall of cotton linters. Figure 8 shows such a layer in the form of a thin membrane after one-hour beating in a Valley beater. Several loose bundles of fibrils start to appear on the surface of the fibers simultaneously with the membranous wall layers. With further beating the number of these bundles increases. The larger bundles are split and finer, and finer bundles of fibrils appear. The splitting also affects the thin membranes and in the later stages of beating they are not found. As indicated by the high specific surface values found on beaten and dried cotton linters, the split-off fibrils are rather stiff and do not collapse easily. Due to the stiffness of the fibrils the relative bonded areas developed on drying are small. In Fig. 9 an area between two adjacent fibers is shown after $2^1/_2$ hr. of beating. The entanglement of the fibrils seen here participates in the formation of a part of the bonding among the fibers. It is quite possible that the more resistant ridges found frequently on the surface of the pulped cotton linters are preventing close contact between the fibers. The contact areas where hydrogen bonds can be formed are also relatively small. As a result the overall relative bonded area is not large enough to develop sufficient strength properties for the paper sheet.

Chemical modification of cotton linters has received a considerable amount of attention during recent years. A large amount of the interest in this area has centered on adaptation of a suitable process for improved beating characteristics and better bonding properties of the cotton linters. Among the chemical modification processes, hydroxyethylation of cotton linters has provided a suitable product for such an application. Laboratory tests and theoretical considerations have

*Fig. 10. Partially hydroxyethylated cotton linters (120×)*

The fibers appear highly swollen but their fibrillar structure is still preserved.

shown that the process can be converted to commercial practice. The suitability of the modified fibers is influenced very strongly by the degree of substitution (D.S) With a high D.S the fibers not only swell but also disperse and partially dissolve on beating. Such a material added to the pulp is capable only of reinforcing to some extent the existing bonds among the pulp fibers. The preservation of the fibrillar structure of the modified fibers is very important. Such partially hydroxyethylated fibers are shown in Fig. 10. A considerable bonding improvement is achieved by blending the modified fibers with untreated cotton linters. As seen in Fig. 11 the swollen hydroxyethylated fibers fibrillate easily on beating. The hydrated material is capable of pulling the fibers together upon drying.

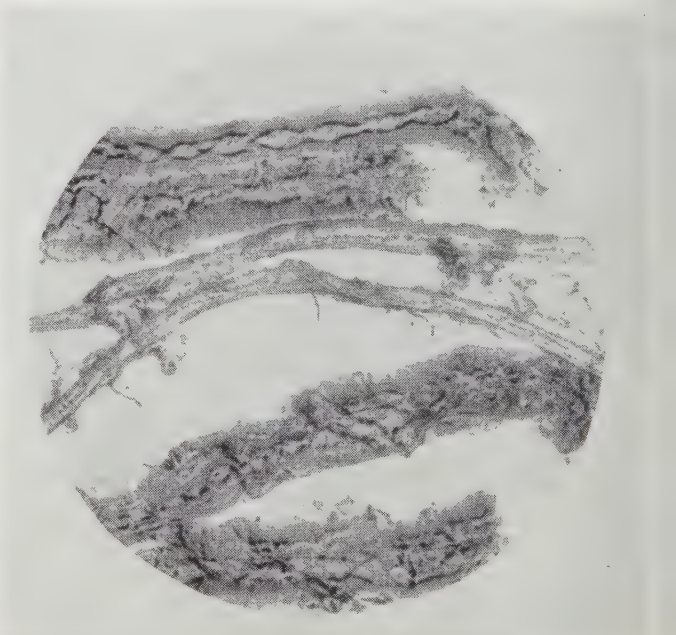

*Fig. 11. A blend of partially hydroxyethylated and untreated cotton linters after beating (120×)*

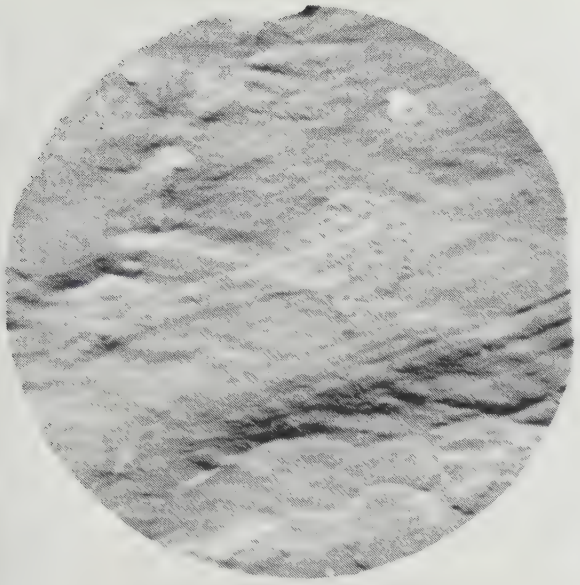

*Fig. 12. Surface replica of a partially hydroxyethylate cotton linter (5900×)*

Besides the fibers, additional bonds are also generated between the adjacent bundles of fibrils. As a result, not only the existing bonds are reinforced but also new bonds are formed and improved strength properties are achieved.

The surface of a cotton linter at an advanced state of hydroxyethylation is shown in Fig. 12. The whole surface area is uniformly swollen and the individual cellulose fibrils appear fused. In Fig. 13 some of the bundles of fibrils are seen still intact on the surface of a partially hydroxyethylated cotton linter. The reacted parts of the fiber wall appear swollen and the swelling extends also to the deeper layers of the fiber wall.

The beating process can also be followed by the differential staining procedure described by Simons

*Fig. 13. Another surface replica of a partially hydroxyethylated cotton linter (5900×)*

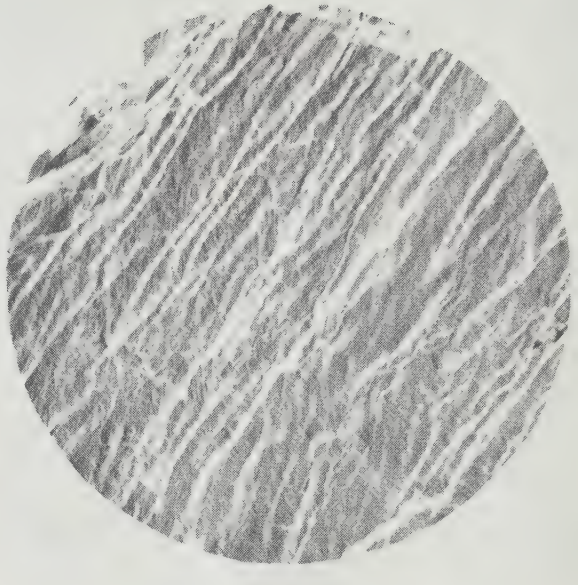

*Fig. 14. A typical surface of a blue stained cotton linter (5900×)*

(*9*). According to this procedure the loosened structure of the fiber walls and progressing hydration of the fibrils and fiber wall fragments are responsible for causing these parts to stain yellow. The unaffected fibers stain blue. Figure 14 shows the surface of a blue-stained, and Fig. 15 of a yellow-stained cotton linters fiber as typical examples. It should be pointed out, however, that the immature and thin walled fibers also stain yellow with this procedure. The differential staining seems to depend entirely on the difference in the rate of diffusion of the blue dye from the fiber walls. The blue dye diffuses easily from the fibers with open wall structure or hydrated cellulosic material. Retained in the fiber walls it masks the staining effect of the yellow component completely and the fiber appears blue.

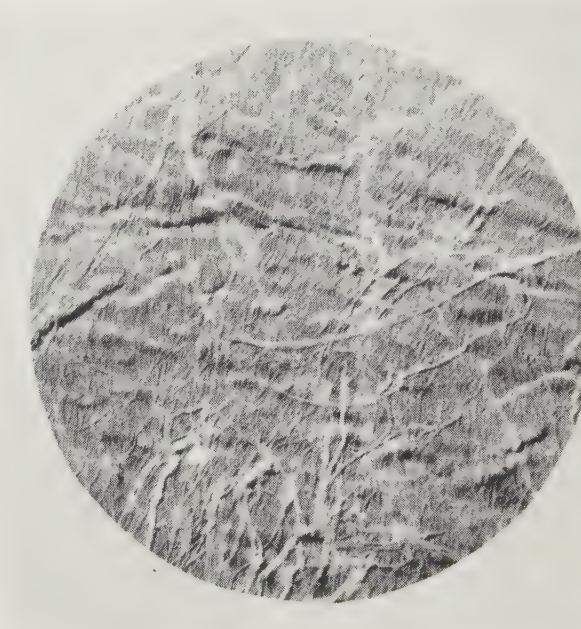

*Fig. 15. A typical surface of a yellow stained cotton linter (5900×)*

Another approach for studying the surface structure of cotton linters is provided by treating the fibers with enzyme solutions. The surface of a raw cotton linter treated with enzyme solution of a commercial product Pectinol R-10 is shown in Fig. 16. As seen from the electronmicrograph a selective attack on the primary wall of the fiber is indicated. Digestion of the pectic

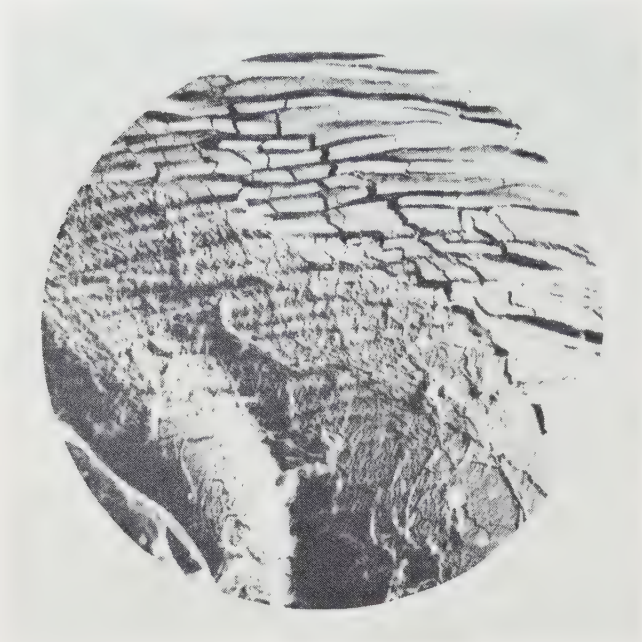

*Fig. 16. A surface replica of a cotton linter treated with an enzyme solution (5900×)*

The remains of the primary wall appear in the center of the electronmicrograph.

materials has resulted in a considerable loss of material in this layer. Loosening of the bonds between the primary and the secondary wall of the fiber is also indicated. The residual cellulose fibrils from the primary wall are seen as pushed together network of these fibrils in the center area of the micrograph. Unattacked areas of the secondary wall appear in the periphery.

## CONCLUSIONS

Electron microscopic evidence indicates that cotton linters have essentially the same surface structure as cotton staple fibers. The surface of these fibers appears creased, with the ridges running at an angle around the fibers. It is believed that the ridges develop on drying of the young cotton fibers. By extraction of waxes and pectic substances from raw cotton linters the cellulosic bundles of fibrils become discernible. Solvent drying causes a swollen appearance of the fibrils, and apparently prevents tight bonding of individual fibrils. Commercial pulping processes affect the surface structure of the fibers considerably more than simple extractions. Quite frequently the surface ridges are eliminated. The elimination of the ridges appears to be more pronounced on the staple fibers. As a general rule, the primary wall is removed by pulping from both types of cotton fibers. The surface of the cotton linters is covered either by the outside layer of the secondary wall, or by the subsequent deeper layers of this wall. The fibrillar bundles from the primary wall, and often also bundles from the outer layer of the secondary wall, are frequently observed as discontinued remains and fibrillar entanglements on the surface of the fibers. The bundles of fibrils in the outside layer of the secondary wall form helix angles from 50 to 60°. The helix angles in the deeper layers of the secondary wall are from 24 to 30°.

The increased importance of cotton linters in the paper industry, caused by the shortage of cotton rags, has resulted in a considerable amount of research interest in improvement of the beating characteristics of these fibers. At least a part of the inherent beating difficulties of cotton linters can be explained by the stiffness of the split-off fibrils and by the more resistant surface ridges encountered on these fibers. The initial stages of beating frequently loosen the outside wall layers in the form of thin membranes. With advanced beating these membranes are split into individual bundles of fibrils and additional fibrils are split off the fiber wall. There seems to be a sufficient number of fibrils to form entanglements representing a part of the interfiber bonding forces. The stiffness of the fibrils and their inability to collapse easily prevent the developing of the necessary strength properties. Adaptation of partially hydroxyethylated cotton linters to improve beating characteristics of these fibers has resulted in a significant strength improvement. It is imperative, however, that the fibrillar structure of the chemically modified fibers be preserved. Blending such fibers with untreated cotton linters strengthens the interfiber bonds considerably. The added material reinforces not only the existing bonds but is capable of producing new bonds by pulling together individual fibrils and whole fibers.

The differentiation among fibers stained with the Simons stain can be traced to the differences in the fibrillar network of the fiber walls. These differences represent either loosening of the fibrillar network by beating, or they are due to inherent variations of the fiber walls as exhibited by the immature and thin walled fibers. In each case the differential staining is based upon differences in the rate of diffusion of the blue dye.

A selective attack on the pectic materials by an enzyme solution causes a partial dissolution of the primary wall of raw cotton linters. As a result this layer of the wall is loosened from the rest of the fiber. The residual cellulosic bundles of fibrils are pushed together, and these remains of the primary wall cover certain areas of the surface of the fibers.

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# Morphological Properties of Cotton and Wood Fibers

## *II. Slash Pine*

K. A. JURBERGS

**The changes imparted by the chemical isolation processes of wood fibers from slash pine have been followed by electron microscopic investigation methods. The surface bundles of cellulose fibrils of the holocellulose fibers and to some extent also of the unbleached pulp fibers are masked by a structureless substance, or substances. These bundles are clearly visible on dissolving grade pulp fibers. The surface of the latter fibers is covered mainly by the $S_1$ layer. The $S_1$ consists of two systems of fibrillar bundles with a helix angle of 70°. The $S_1$ layer can be found as a loose sleevelike structure on compression wood and some of the summerwood fibers. It has a negative birefringence and a thickness of 0.4 $\mu$. The $S_1$ is restrictive to swelling of the fibers with such cellulose solvents as dilute cupriethylenediamine. The more resistant parts to homogeneous acetylation are located deeper in the fiber wall and possibly represent the fibrillar bundles located in the four corners of the fiber wall. The different appearance of the lumens of sulfate and sulfite fibers are identified as variables of the pulping processes. Measurements of the fibrillar bundles of both types of fibers indicate a tighter packing of the fibrils in sulfate fibers.**

Owing to the importance of wood as a raw material the morphology of the different wood tissue cells has received a considerable amount of attention. Research workers in many diversified fields have contributed to the present day rather general detailed knowledge of the architecture of the wood cell walls. However, the great number of complex natural variations encountered and the limitations of the applicable methods have left several of the areas unexplored. Further work is still necessary to fill in the existing gaps in our knowledge of the morphology of the wood cells.

Without attempting to give a complete history of the developments in fiber morphology, several of the more recent contributions will be briefly mentioned. The present-day terminology originates mainly from the work of Kerr and Bailey (*1*). Although the scope of knowledge on the subject has increased tremendously, the majority of the workers in the field have retained these terms and describe their new findings in the framework of the old terminology. Others, notably Frey-Wyssling (*2*), Bucher (*3*), and Meier (*4*), are strongly advocating the introduction of new terms. The disagreement concerns mainly the different layers of the secondary fiber wall. The terms "outer" and "inner" layers of the secondary wall from the older terminology are replaced by the last mentioned group of authors with "transition lamella" and "tertiary wall," respectively. The older terminology is used throughout the present article.

The transition area from chemical macromolecules of cellulose to the formation of the cellulose fibrils as structural elements of the wood cell walls is also discussed by Frey-Wyssling (*2*), Ranby (*5*), and Preston (*6, 7*). These authors have given a comprehensive description of the structural principles involved starting from the unit cell of the cellulose through the formation of cellulose fibrils and subsequently the whole fiber wall. Lange (*8*) has described the principal chemical and morphological concepts of the hardwood fibers. The author has previously discussed some aspects of morphology of slash pine and sweet gum fibers (*9*). Emerton and Goldsmith (*10*) have presented evidence which has radically changed the previous concepts of the structure of the outside layer of the secondary wall (the $S_1$ layer). Wardrop and Dadswell (*11*) have described the variations of the structure of the different wall layers of different types of fibers, such as reaction wood fibers compared to normal fibers.

### MATERIALS AND METHODS

Slash pine (*Pinus elliottii*, Egelm) has been chosen as the principal wood species for the investigations described here. The wood samples were obtained from slash pine trees grown in northern Florida. The majority of the pulp samples used in this work have been either laboratory or pilot plant preparations.

Two principal techniques were used for the electron microscopy part of the investigations. The first one was a one-step negative chromium replication technique described more fully in the Part I of this article. Specimens for the electron microscopy were also prepared by mechanical disintegration of the fiber wall material. The fibers were disintegrated for 5 min. in a semimicro Waring Blendor. A dispersion of the disintegration products was dried on an electron microscope specimen grid covered previously with a carbon or cellulose nitrate membrane. The specimens were then shadowed with chromium at a low angle (20°).

A phase microscope was used almost exclusively for the swelling studies. The refractive index of the highly swollen fibers differs only slightly from that of the surrounding cellulose solution. Viewed in an ordinary light microscope the contrast is too low for differentiation. Staining of the fibers usually did not improve the contrast because of leaching of the dyes from the fiber wall. The increased contrast offered by the phase microscope provided excellent means for examination of the swelling phenomena. Conventional microtomic and microscopic methods, using ordinary light and polarizing microscopes, were used for the rest of the microscopic studies.

### RESULTS AND DISCUSSION

Contrary to the cotton fibers individual wood fibers are rather hard to obtain in the native form. A rather severe chemical treatment is necessary to isolate the

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*Fig. 1. An electronmicrograph of the surface of a summerwood slash pine holocellulose fiber isolated by the chlorite process (5900×)*

fibers from the network of the woody tissues. Undoubtedly, such treatments affect the isolated fibers and it seems probable that the original may escape direct observations.

The different procedures employed in preparation of holocellulose represent a rather mild treatment for isolation of individual wood fibers. Figure 1 represents a typical electronmicrograph of a surface of a slash pine summerwood holocellulose fiber isolated by the chlorite process (*12*). The cellulose fibrils are completely masked by a structureless substance, possibly residues of lignin and hemicelluloses. Extraction of the holocellulose fibers with dilute sodium hydroxide removes a part of the masking material. The cellulose fibrils become discernible, although not very distinctly. The surface of such an extracted holocellulose fiber is shown in Fig. 2.

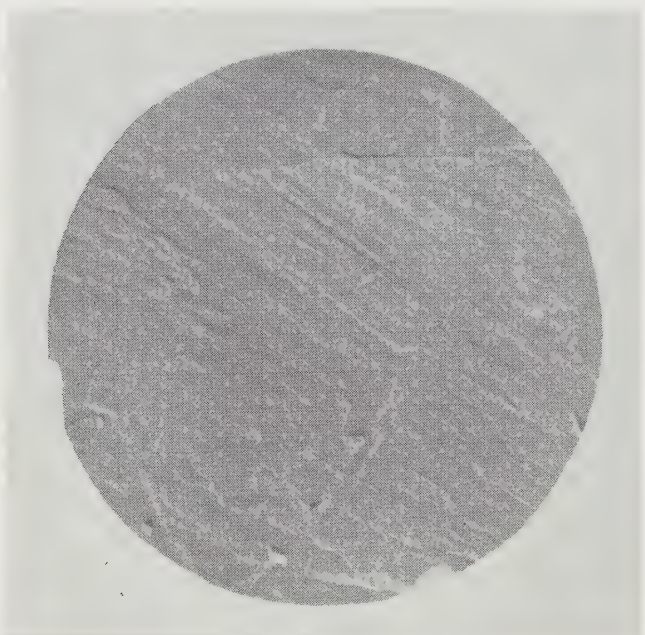

*Fig. 2. The surface of a chlorite holocellulose fiber extracted with dilute sodium hydroxide soln. (5900×)*

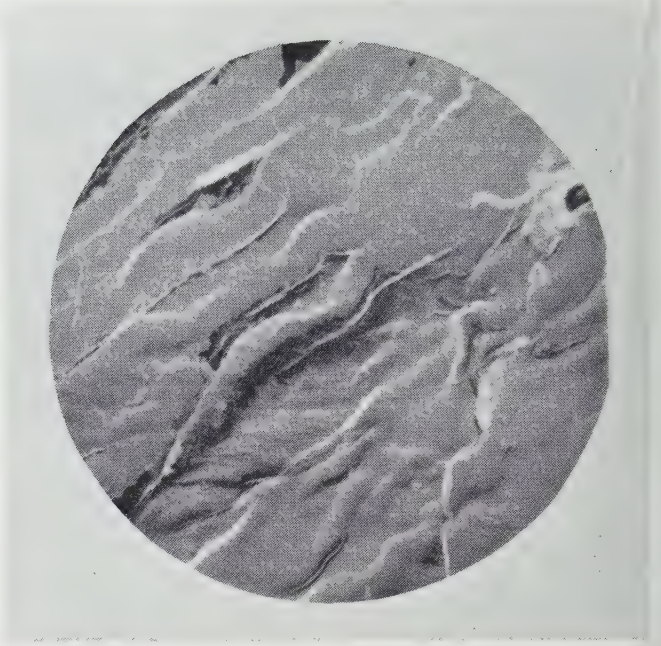

*Fig. 3. The surface of an unbleached sulfite slash pine fiber (5900×)*

The different chemical pulping processes affect the substances in the fiber walls considerably more. The surface of an unbleached summerwood fiber pulped by the sulfite process is shown in the electronmicrograph in Fig. 3. The underlying fibrillar cellulosic structure is still masked by the presence of a structureless substance, or substances. Subsequent purification processes remove a considerable part of the noncellulosic material and the cellulose fibrils become clearly discernible. Corroborative evidence is also obtained by mechanical disintegration of the fiber wall material. This technique gives only a limited amount of information concerning the structure of the native fiber. Only in a few cases can the dispersed material be properly identified as

*Fig. 4. Chlorite holocellulose mechanically disintegrated for 5 min. in a Waring Blendor. Low angle chromium shadowing (5900×)*

*Fig. 5. Sulfate pine fibers mechanically disintegrated for 5 min. in a Waring Blendor. Low angle chromium shadowing (5900×)*

originating from a certain location of the fiber wall. However, the size and shape of the dispersed material indicate not only the ease of disintegration, but also the inherent differences traceable to the wood species, or the process conditions by which these fibers have been isolated. An electronmicrograph of such dispersed material obtained by mechanical disintegration of holocellulose fibers is seen in Fig. 4. Comparatively large bundles of cellulosic fibrils are noticeable. In Fig. 5 similar bundles of fibrils are seen as the distintegration products from bleached sulfate fibers. In this case the bundles of fibrils are much finer. Both specimens were prepared under identical disintegration conditions.

As a general rule pulping and purification process remove the primary wall $P$ from the dissolving grade wood pulp fibers almost completely (*9*). There are

*Fig. 6. The surface of a sulfite pine fiber from a shive (5900×)*

*Fig. 7. A characteristic surface structure of a slash pine sulfate fiber from a dissolving grade pulp (5900×)*

some indications that the removal of $P$ is less complete by the sulfite process. Isolated areas still covered with the $P$ are found more frequently on the surfaces of these fibers than on the fibers pulped by the sulfate process. Large surface areas covered by the $P$ are usually found on fibers from shieves as seen in Fig. 6. The fibers contained in a shive pass through the purification processes physically protected. The primary wall of these fibers is considerably better preserved.

Generally, the surface of the wood pulp fibers is covered by the outside layer of the secondary wall $S_1$. Figure 7 shows a typical surface structure of a bleached sulfate fiber from slash pine. A similar surface of a sweet gum fiber tracheid is depicted in Fig. 8. As seen from these electronmicrographs, the $S_1$ in both cases consists of two symmetrically intersecting systems of cellulosic fibrils running in broad $Z$ and $S$ spirals around fiber axis. The average value of the intersecting angle

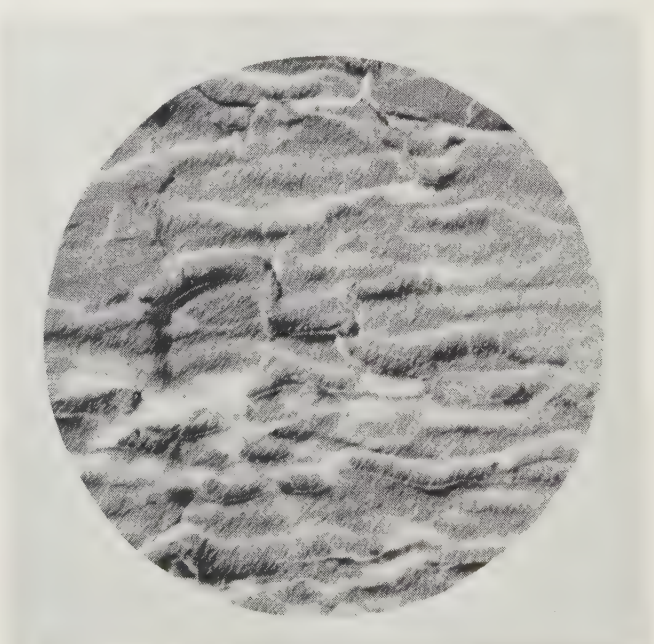

*Fig. 8. The surface of a sweet gum fiber tracheid (5900×)*

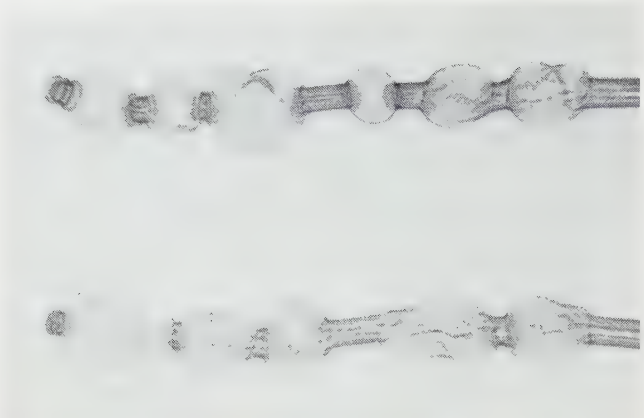

*Fig. 9. Slash pine summerwood fibers swollen in dilute cupriethylenediamine soln. (100×)*

is approximately 140°, giving a helix angle near 70° for the fibrillar spirals in each of the two systems. The $S_1$ layer is rather complex and the concepts about its structure have undergone a considerable evolution recently. First it was thought that the $S_1$ consists of one system of rather flat spirals. A general agreement seems to be established now that there are two intersecting systems of fibrils, at least in the surface layers of this structure. The structure of the deeper layers of the $S_1$ does not seem to be fully established as yet. The possible structure of these layers will be discussed more fully subsequently.

Treating the pulp fibers with reagents, such as dilute cupriethylenediamine, in which cellulose swells and eventually dissolves provides a means to study their wall structure more closely. When a fiber starts to swell the structural differences of the various wall layers become apparent and influence the whole swelling process. The well known swelling phenomena are the results from the complex interactions of the swelling media and the different wall layers. The arrangement of the fibrils in the $S_1$ makes this layer very resistant to transversal expansion, or contraction. The middle layer of the secondary wall $S_2$, on the other hand, expands transversally very easily. When the $S_2$ layer starts to swell and expand, the resistant $S_1$ exerts a considerable pressure restricting the overall swelling of the fiber. The bonds between adjacent bundles of fibrils in the $S_1$ apparently are not affected very uniformly during the pulp purification. The bundles of fibrils in the weaker places split apart eventually and the swollen $S_2$ bulges out through the splits. The well-known

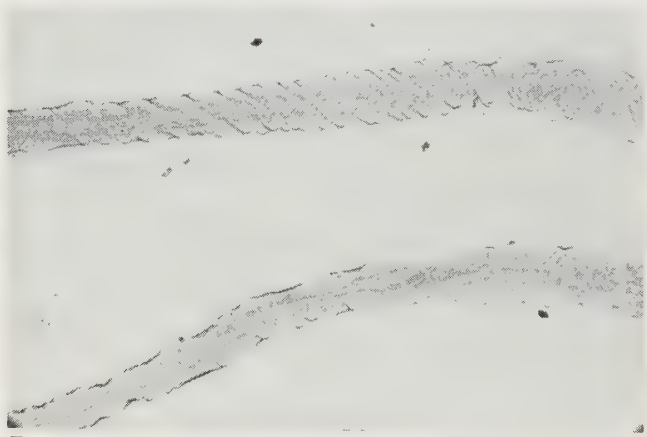

*Fig. 10. Slash pine summerwood fibers swollen in dilute cupriethylenediamine soln. (100×)*

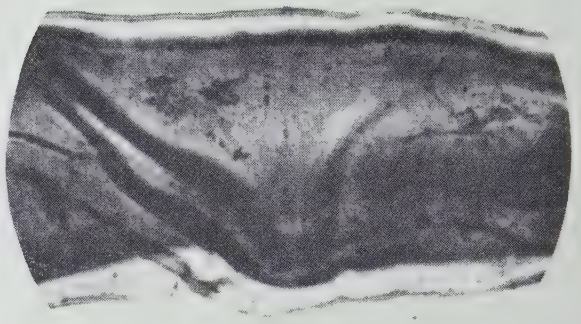

*Fig. 11. A transparent surface layer of a slash pine fiber (800×)*

balloons appear as seen in Fig. 9. The expanding $S_2$ pushes the spirals together in the form of constricting rings between adjacent balloons. In case the interfibril bonds in the $S_1$ are more uniformly weakened throughout the layer, the splits do not occur but the weakened $S_1$ allows the $S_2$ layer to expand. The swollen fiber appears covered with a network of spirals as seen in Fig. 10.

The origin of the spirals which appear on the surface of the swelling fibers and are observable with an ordinary light microscope is still not completely understood. The two systems of fibrils in the $S_1$ discussed earlier are visible only with an electron microscope. The average diameter of these bundles of microfibrils are from 250 to 350 A. Electron microscopic evidence of any superstructure of fibrillar bundles of large dimensions has never been found. The spirals visible under the light microscope, on the other hand, are a few microns wide. Apparently there are two different systems of fibrillar bundles in $S_1$ which may be related to each other. However, such a relationship has never been demonstrated. It is quite possible that the larger system of spirals represent aggregates of the smaller bundles. The larger spirals seem to be most conspicuous during certain phases of the swelling. Two systems of $Z$ and $S$ spirals are observed, although quite frequently only for a very short time. In the course of continued swelling the number of spirals decreases rapidly. Apparently the weaker spirals dissolve. The remaining spirals belong only to one system, they display either the $Z$ or the $S$ form.

Almost all compression wood fibers and a large portion of the regular summerwood fibers of pine pulps are quite frequently found covered with a transparent layer. Such a transparent sleeve covering a pine fiber is seen in Fig. 11. It appears to be around 5 $\mu$ thick and does not seem to have any visible structure. Under the polarizing microscope the isolated sleeves show a negative birefringence and its real thickness was found to be about 0.4 $\mu$. Apparently in its original location this layer hangs loosely around the fibers. On the basis

of these observations the layer was identified as the $S_1$ layer. Apparently, the $S_1$ layer is loosened during pulping and purification. This is possibly achieved by dissolving and removing lignin which, according to the accepted concepts, is present in the outer layers of the secondary wall in comparatively high concentration. Pulping also causes a considerable shrinkage of the wood fibers. It is conceivable that the $S_1$ layer does not shrink along with the shrinking $S_2$. An empty space is generated between $S_1$ and $S_2$ and the former envelops the fiber literally as a sleeve.

Homogeneous acetylation of pine pulp fibers provides another approach for closer microscopical studies of the morphology of the fiber walls. Acetylation represents a different mechanism of attack on the fiber walls than the mechanism displayed by such cellulose solvents as cupriethylenediamine, cuprammonium, and phosphoric acid. The acetylation seems to affect the more accessible, possibly the unordered or less well-ordered, parts of the fiber wall first. The soluble portion diffuses outward through the fiber wall and envelops the fiber in a cloudlike formation. The fiber appears highly swollen, and only when the enveloping material is washed away, is the almost intact fiber outline seen underneath. The acetylation phases of pine summerwood fibers are illustrated in Fig. 12. The fiber is somewhat swollen but only to a slight extent.

With progressing acetylation more of the fiber wall material is dissolved and dispersed. The more resistant parts of the fiber wall become visible as seen in Fig. 12. The skeleton-like structures are seen as two elongated bars. Their exact location in the fiber wall is very difficult to establish. They seem to be located beneath the surface of the fiber, but not deep enough so that $S_3$ may be suspected as a possible location. The $S_2$ layer is highly uniform and it cannot be expected that a part of its fibrils should be so much more resistant than the rest. Apparently, these resistant structures are part of the $S_1$ and can be identified as the longitudinal bundles of fibrils as suggested by Emerton and Goldsmith (*10*). These bundles are located in the four corners of the fiber wall. Since a typical summerwood fiber tends to lie on one of its tangential faces, the bundles in the corners of the radial walls are superimposed. Usually two bars are observed as the resistant structures of each fiber. Closer examination, however, reveals that each of the bars actually consists of two parts. The same corner structures can also be observed as bulges on the surface of pulped fibers, either with a light or an electron microscope.

Mechanically isolated $S_1$ layers show a membranous structure with a rather uniform thickness. The corner bundles of fibrils have never been observed with these membranes. These structures have either been split from the $S_1$ by stripping it from the fiber, or they do not belong to the $S_1$ layer but represent entirely separate structures located between the $S_1$ and $S_2$. The former assumption is supported by the observations that weak

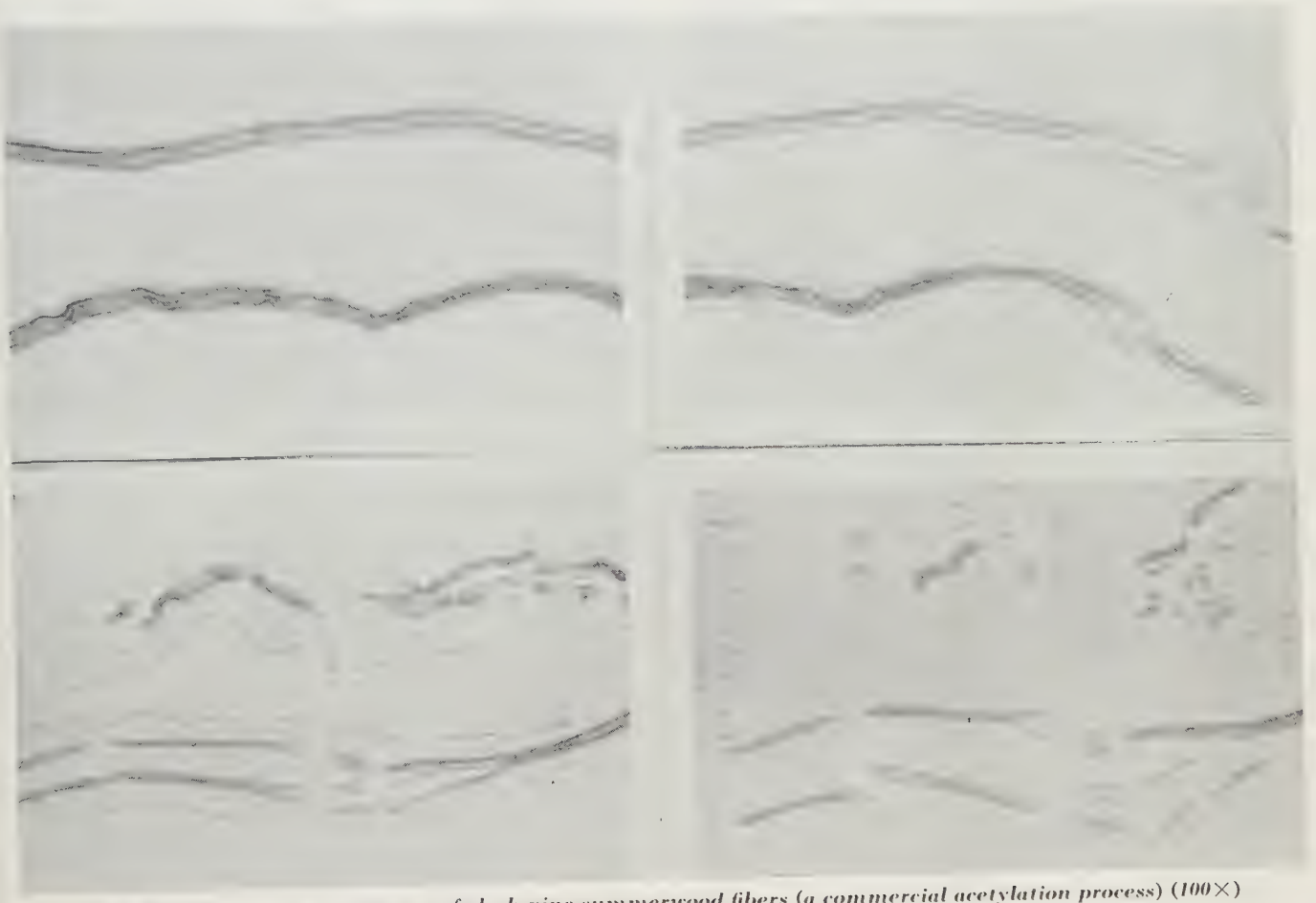

*Fig. 12. Acetylation sequences of slash pine summerwood fibers (a commercial acetylation process) (100×)*

*Fig. 13. A sulfate pine summerwood fiber (600×)*

spirals are found on swollen fibers from which the $S_1$ has been mechanically stripped. Apparently the splits occur inside the $S_1$ layer when this layer is loosened from the fiber during pulping and purification.

Different mechanisms seem to be involved in the shrinking of pine fibers pulped by the sulfate and the sulfite process. As seen in Fig. 13 a very well-defined lumen can be seen inside a sulfate fiber. The lumen is frequently almost completely closed in the sulfite fibers. Such a fiber is shown in Fig. 14. The two pulps have been prepared by the two pulping processes using a common batch of pinewood chips. Since the cross-sectional areas for both fiber types are almost identical, the conclusion must be drawn that the walls of the sulfite fibers have expanded inwardly and that the cellulose density of the sulfite fibers should be considerably lower than that of the sulfate fibers. The $S_3$ layer appears considerably weakened in the sulfite fibers.

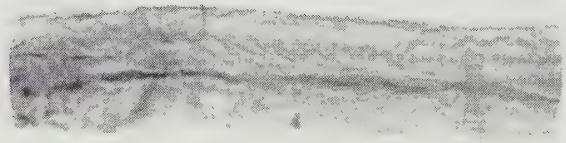

*Fig. 14. A sulfite pine summerwood fiber (600×)*

*Fig. 15. Cross sections of pine sulfate pulp fibers (350×)*

The differences between the two fiber types can also be seen on cross sections of these fibers. In Fig. 15 a cross section of a sulfate, and in Fig. 16 of a sulfite pulp sheet are shown.

**Table I. Diameter of the Fibrillar Bundles (in Angstroms)**

| | P | | | $S_1$ | | |
|---|---|---|---|---|---|---|
| *Sample* | *Small* | *Average* | *Large* | *Small* | *Average* | *Large* |
| Sulfate | 220 | 380 | 600–650 | 220 | 300 | 440–750 |
| Sulfite | 150 | 175 | 600–900 | 160 | 175 | 300 |

Jayme and Hunger (*13*) have reported that the fibrillar bundles of sulfate fibers are larger than on sulfite fibers from the same wood species. This observation is confirmed by our work on sulfate and sulfite fibers pulped from a common batch of pinewood chips. The results from measurements on electronmicrographs of surface replicas are summarized in Table I.

*Fig. 16. Cross sections of pine sulfite pulp fibers (350×)*

## CONCLUSION

Any chemical process used for isolation of individual wood fibers causes some changes in the native structure of these fibers. The changes imparted to the fiber walls can be investigated by electron and light microscopic methods. The surface of a slash pine holocellulose fiber appears structureless. No signs of the characteristic cellulose fibrils can be detected. The structureless material on the surface of these fibers possibly consists of lignin residues and hemicelluloses. After extraction with dilute caustic solution the cellulose fibrils become discernible.

Commercial pulping processes constitute a harsher treatment used for isolation of wood fibers. Depending on the desired end-product, and the severity of the pulping and purification processes employed, the fiber walls are more or less affected. Unbleached pulp fibers differ only slightly from the holocellulose fibers. Fully purified commercial dissolving pulp fibers, however, exhibit some conspicuous differences compared to the holocellulose fibers. Much less of the structureless material can be found on the fibers. The same relationship between these two types of fibers can be found by electron microscopic examination of the disintegration products of the fiber wall material.

Commercial pulping and purification of dissolving grade wood pulps remove the primary wall $P$ almost completely from the pulp fibers. There is some evidence that the removal is less complete from fibers pulped by the sulfite process. The surface of the fibers is covered almost exclusively by the outside layer of the secondary wall $S_1$. Occasionally this layer also can be partially removed. Remains from $P$ and $S_1$ are frequently found on the fibers in the form of disarranged fibrillar entanglements. The $S_1$ layer consists of two intersecting systems of fibrils. Both systems are symmetrical to each other and to the fiber axis, and have a helix angle of near 70°.

The transparent sleevelike structures observed on almost every compression wood fiber and quite frequently on summerwood fibers from slash pine have been identified as the $S_1$ layers of these fibers. The $S_1$ layer in these cases apparently is split off the rest of the fiber wall during pulping and purification and is encasing the fiber loosely. This layer can be mechanically removed from some of the fibers. Under the polarizing microscope it shows a negative birefringence and its thickness has been determined as 0.4 $\mu$.

Swelling studies of the pulp fibers with such cellulose solvents as dilute curpriethylenediamine solution provide convenient means for studying the morphology of these fibers. Characteristic swelling patterns are observed which depend mainly on the condition of the $S_1$, but also to some extent on the condition of the whole fiber wall. A nonuniform weakening of the $S_1$ causes splits at these weak places between the fibrils in this layer when the fiber is subjected to swelling. The transversally expanding $S_2$ bulges out through the splits and the well-known balloons are formed. The fibrillar spirals in the nonexpanding $S_1$ are pushed together by the expanding balloons forming constricting rings between adjacent balloons. If the $S_1$ is more uniformly affected it loses a part of its restrictive properties and an over-all swelling of the whole fiber is observed. In certain phases of the swelling, two systems of fibrils can be seen covering the fiber surface as a fine network of spirals. The number of the spirals gradually decreases and with continued swelling only one system of spirals remains on the surface of the fibers as a dominant system. It is impossible to determine the original intersecting angle of the two systems. Although the fibrillar systems just discussed seem to resemble the fibrillar systems detectable with the electron microscope, their dimensions and possibly also the intersecting angles are quite different. The diameters of the fibrillar bundles from the system detected with the light microscope are at least 100 times greater than those discussed above that were detected by electron microscopy. The relationship between the two types of fibrillar systems is not completely understood. It is possible that the larger bundles are aggregation products of the smaller ones.

The disintegration pattern of the fibers subjected to homogeneous acetylation is completely different from the one just discussed. The acetylation reagents penetrate the fiber walls and apparently attack the more easily accessible parts of the cellulose first. The dispersed and partially dissolved material diffuses from the fiber wall and envelops the fiber in a cloudlike structure. The fibers appear to be swollen, and only if the diffused material is washed away can the true dissolution mechanism be ascertained. The more resistant parts of the fiber wall to acetylation are located deeper inside the wall. These resistant parts are observed as two barlike structures. Each of the bars apparently consists of two or more rodlike structures. These structures are tentatively identified as the fibrillar bundles located in the four corners of the fiber wall and running parallel to the fiber axis. The question as to which part of the fiber wall these bundles belong must be left open at the present. They appear to be a part of the deeper layers of the $S_1$. However, if the $S_1$ layer is stripped off, these bundles apparently remain with the rest of the fiber. Swelling investigations of fibers from which $S_1$ hss been stripped indicate that a part of the spirals from this layer has remained on the fiber surface. It is quite possible that the $S_1$ layer is really split by the pulping processes, or on attempts to remove it mechanically.

The structural variables traceable to the pulping processes have been investigated by preparing sulfate and sulfite pulps from a common batch of slash pine chips. The different process effects on the fiber walls is indicated by the differences in appearance of the lumens of the fibers. The lumen of a sulfate fiber is clearly seen through the semitransparent fiber walls. The lumen of the sulfite fiber is frequently collapsed. Since the cross-sectional areas of the two fibers are almost identical, the closing of the lumen in the case of a sulfite fiber should be due to the inward expansion of the fiber wall. The tertiary wall seems to be more strongly affected (weakened) by the sulfite pulping process.

The suggested vitrification of the cellulose fibrils in the wall of sulfate fibers is substantiated, to some extent, by measurements of the fibrillar bundles of the two types of fibers. The diameters of the bundles of fibrils from either the remains of $P$ or the $S_1$ layer are greater in the sulfate fibers.

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# Studies on the Chemistry of Aspenwood

## V. An Investigation of Various Aspen Spent Liquors as Sources of p-Hydroxybenzoic Acid and Other Compounds

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**The suitability of the spent liquors from the pulping of aspenwood by the acid sulfite, neutral sulfite, kraft, and soda processes as sources of *p*-hydroxybenzoic acid and other aromatic compounds was studied and compared with aspenwood. Acid sulfite, kraft, and soda spent liquors proved to be satisfactory raw materials for *p*-hydroxybenzoic acid recovery, but neutral sulfite semichemical spent liquor yielded only a small percentage of the *p*-hydroxybenzoic acid originally present in the wood. Aspenwood and aspen spent pulping liquors were submitted to both acid and alkaline hydrolysis, and the vanillin, syringaldehyde, *p*-hydroxybenzaldehyde, vanillic acid, syringic acid, *p*-hydroxybenzoic acid, and *p*-coumaric acid produced were determined by means of paper chromatography and ultraviolet spectrophotometry. Material balances were made. In addition, paper chromatography indicated several unknown compounds to be present in these reaction mixtures. Quantitative data on known compounds indicate that unbleached pulps may have considerable *p*-hydroxybenzoic acid and other compound-yielding materials present.**

Earlier studies on the isolation of *p*-hydroxybenzoic acid from the spent sulfite liquors from the commercial pulping of mixed aspens and from the laboratory pulping of quaking aspen (*Populus tremuloides*) (*1*) led to a study of other pulping liquors as a source of *p*-hydroxybenzoic acid, a chemical much in demand for the production of polyester materials. Other studies in our laboratories on the alkaline hydrolysis of representative hardwoods (*2–5*) indicated that only members of the *Salicaceae* family comprising the *Salix* and *Populus* genera yielded substantial quantities of *p*-hydroxybenzoic acid upon alkaline hydrolysis. Accordingly, only pulping liquors derived from these two genera were considered, and for practical purposes, the experiments reported herein were limited to studies on commercial liquors from the pulping of mixed *Populus* species and laboratory liquors from the pulping of *P. tremuloides*. The present paper reports several studies on the suitability of the spent liquors from the pulping of aspenwood by the acid sulfite, neutral sulfite, kraft, and soda processes as sources of *p*-hydroxybenzoic acid and other aromatic compounds. Yields obtained are compared with those obtainable from aspenwood directly.

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### PRELIMINARY STUDIES

The first study in this investigation was concerned with the potential *p*-hydroxybenzoic acid recovery from several aspen spent sulfite liquors. Four liquors were employed in this preliminary study as follows:

Liquor I was an ether-extracted concentrated commerical ammonia-base spent sulfite liquor from the cooking of mixed peeled aspens (*Populus tremuloides*, *P. grandidentata*, and *P. tacamahaca*). This liquor contained 39.95 g. solids per 100 g. of liquor, and the solids contained 7.93% methoxyl. The original liquor was obtained from the Charmin Paper Products Co., Green Bay, Wis., in January, 1956.

Liquor II was a digester-strength aspen spent liquor from the ammonia-base acid sulfite cooking of mixed peeled aspens obtained from the Charmin Paper Products Co. in June, 1955. This liquor contained 10.26 g. solids per 100 g. of liquor, and the solids contained 7.40% methoxyl.

Liquor III was a digester-strength neutral sulfite spent liquor from the laboratory pulping of authentic *Populus tremuloides* sapwood to give a 70% yield of "easy bleaching" pulp. The liquor contained 10.66 g. solids per 100 g. of liquor.

Liquor IV was the combined spent liquor and washings from the laboratory sodium-base acid sulfite pulping of authentic *P. tremuloides* described earlier (*1*). This liquor contained 2.81 g. of solids per 100 g. of liquor, and the solids contained 7.34% methoxyl.

The yield of *p*-hydroxybenzoic acid was determined for these liquors directly, after alkaline hydrolysis, and after acid hydrolysis.

Direct determination of *p*-hydroxybenzoic acid was made by acidifying an amount of liquor containing 80 g. of solids with 30 g. of 33% sulfuric acid and extracting with ether in the air-agitated, liquid-liquid continuous extractor (*6*) for 24 hr. The ether was dried and concentrated to a small volume.

For alkaline hydrolysis, the same amount of liquor was treated with 50 g. of solid sodium hydroxide pellets

Table I. Analyses of Aspen Spent Liquors Before and After Hydrolysis with Acid and with Alkali

| Liquor | Ether extract, %[a] | Vanillin, %[b] | Syringaldehyde, % | Ratio[c] S/V | Vanillic acid, %[b] | Syringic acid, %[b] | p-Hydroxybenzoic acid— % | p-Hydroxybenzoic acid— g.[d] |
|---|---|---|---|---|---|---|---|---|
| I—Direct | 1.8 | 0.4 | 0.21 | 0.43 | 0.6 | 0.5 | 1.3 | 0.0183 |
| I—NaOH-hydrolyzed | 8.0 | 2.8 | 2.1 | 0.63 | 0.6 | 0.9 | 7.3 | 0.4662 |
| I—$H_2SO_4$-hydrolyzed | 1.4 | 0.4 | 0.8 | 1.67 | 1.5 | 1.7 | 20.3 | 0.2238 |
| II—Direct | 2.4 | 0.5 | 0.6 | 1.00 | 2.7 | 2.4 | 14.8 | 0.2865 |
| II—NaOH-hydrolyzed | 5.2 | 2.4 | 2.0 | 0.70 | 1.2 | 1.0 | 10.7 | 0.5400 |
| II—$H_2SO_4$-hydrolyzed | 1.7 | 1.5 | 1.0 | 0.58 | 2.8 | 2.6 | 30.9 | 0.4290 |
| III—Direct | 1.6 | 2.1 | 2.9 | 1.15 | 1.3 | 1.4 | 2.1 | 0.0272 |
| III—NaOH-hydrolyzed | 0.9 | 4.3 | 4.5 | 0.87 | 3.5 | 4.3 | 2.6 | 0.0180 |
| IV—Direct | 1.7 | 0.5 | 0.5 | 0.83 | 2.0 | 2.8 | 17.0 | 0.2340 |
| IV—NaOH-hydrolyzed | 10.3 | 2.0 | 2.5 | 1.04 | 1.0 | 2.2 | 10.3 | 0.8474 |
| IV—$H_2SO_4$-hydrolyzed | 1.8 | 0.4 | 0.7 | 1.46 | 1.0 | 2.6 | 25.6 | 0.3687 |

[a] The % of ether extract is on the basis of the original 80 g. of solids in each experiment.
[b] The % of vanillin and all the other compounds is on the basis of the ether extract for the particular experiment.
[c] The ratio of syringaldehyde to vanillin is on the molar basis.
[d] The weight of *p*-hydroxybenzoic acid is that present in the entire ether extract for the particular experiment.

and boiled under reflux for 6 hr. The alkaline reaction mixture was cooled, acidified with dilute sulfuric acid, and extracted in the same manner with ether. The ether was dried and concentrated to a small volume.

Acid hydrolysis was accomplished by treating the same amount of liquor with 120 g. of 33% sulfuric acid and boiling the mixture under reflux for 6 hr. The mixture was cooled and extracted continuously with ether as above. The ether was dried and concentrated to a small volume.

All ether solutions were submitted to total solids analyses, and yields were determined. All ether solutions were chromatographed in three different solvent systems, and the chromatograms were sprayed with four different spray reagents. Solvent systems used were: butanol-2% aqueous ammonia, 10:3:3 butanol-pyridine-water, and *n*-butyl ether saturated with water. The spray reagents employed were bis-diazotized benzidine, 2,4-dinitrophenylhydrazine, ferric chloride, and the Mäule reagents.

These qualitative paper chromatograms indicated *p*-hydroxybenzoic acid, syringic acid, vanillic acid, vanillin, and syringaldehyde to be present in all of the ether extracts. In addition, a number of unidentified spots appeared on all chromatograms. (Since this work was performed, two of these spots have been identified as *p*-coumaric acid and acetosyringone.) All identified compounds were determined quantitatively in all of the ether extracts by the chromatographic and spectrophotometric procedures described in detail in earlier papers (*2, 3*). Data for these quantitative experiments are given in Table I along with yield data for the ether extracts.

The quantitative data of Table I demonstrate several interesting facts.

1. Sodium hydroxide hydrolysis greatly increases the amount of ether extractives obtainable from an aspen spent sulfite liquor on subsequent acidification. On the other hand, sulfuric acid hydrolysis has much the opposite effect with respect to total ether extractives.

2. Whereas the total ether extractives are not increased by sulfuric acid hydrolysis, the amount of *p*-hydroxybenzoic acid present in the ether extractives is increased markedly. Apparently, ether extractives present in the original spent sulfite liquor are condensed or rendered insoluble in ether by the dilute sulfuric acid boiling.

3. The conditions of alkaline hydrolysis used here are similar to those employed in the past for the production of vanillin and syringaldehyde from spent sulfite liquors (*7*). Consequently, the percentage of *p*-hydroxybenzoic acid present in the ether extract was not as great as might be expected because of the increased amounts of these two aldehydes.

4. There is apparently no relation between conditions of hydrolysis and the syringaldehyde/vanillin ratio in the ether extractives. All ratios are lower than ratios published by other investigators in the past for aldehydes obtained from hardwoods. It should be remembered that, in the present case, no oxidation was employed.

5. The neutral sulfite semichemical cook used in this series of experiments either does not liberate *p*-hydroxybenzoic acid in the spent liquor, or it ties up the acid in a condition unamenable to alkaline hydrolysis. No examination of the pulp was made in this experiment.

## KNOWN COMPOUND BALANCES ON AN ASPEN NEUTRAL SULFITE SEMICHEMICAL COOK

Because of the apparent loss of *p*-hydroxybenzoic acid in the neutral sulfite semichemical cook of aspen noted above, it was desired to determine a *p*-hydroxybenzoic acid balance on a controlled laboratory neutral sulfite semichemical cook of authentic quaking aspen. The cook was performed under conditions excluding air as described previously (*1*).

A 670-g. sample of *P. tremuloides* chips containing 600 g. of ovendry wood was placed in a digester and the digester was evacuated. A neutral sulfite cooking liquor was prepared with the following composition: sodium sulfite, 120 g. (20% based on ovendry wood); sodium bicarbonate, 40 g. (6.7% based on wood); total liquor, 4730 cc. + 70 cc. in chips; liquor strength, 25 g.p.l. sodium sulfite; pH, 8.3. This liquor was sucked into the digester, and nitrogen pressure was applied to 150 to 160 p.s.i. for 15 min. Nitrogen pressure was released and the mixture was heated to 100°C. in 22 min., to 130° in 23 min. to 170° in 10 min., and cooked at 170° for 4 hr. The digester was cooled to 50°, and the liquor was drained. The spent liquor had a pH of 6.9 and a sodium sulfite content of 11.6 g.p.l. The chips were broken up in a Sprout-Waldron refiner, 0.003-in. clearance, using tap water. The pulp was dewatered on muslin cloth, washed with dilute acetic acid to pH 4.0, screened in a flat screen, and dewatered on a Buchner funnel. The pulp yield was 1334 g. containing 75% moisture or 334 g. of pulp on the ovendry basis. The spent liquor amounted to 3385 g. containing 215 g. of solids, and the washings amounted to 1655 g. containing 70 g. of solids.

Table II. Known Compound Data for Neutral Sulfite Semichemical Cook of Aspen

| Starting material | Ether extract, %[a] | Vanillin, %[b] | Syringaldehyde, % | Ratio[c] S/V | Vanillic acid, % | Syringic acid, % | p-Hydroxybenzoic acid, % |
|---|---|---|---|---|---|---|---|
| Original sawdust—hydrolyzed | 2.88 | 1.3 | 1.7 | 1.12 | 1.2 | 1.3 | 12.4 |
| Spent liquor—not hydrolyzed | 1.36 | 1.4 | 1.7 | 0.98 | 1.1 | 1.1 | 10.3 |
| Spent liquor—hydrolyzed | 3.44 | 2.2 | 3.4 | 1.35 | 1.6 | 1.8 | 4.1 |
| Washings—hydrolyzed | 3.73 | 2.0 | 4.3 | 1.78 | 1.6 | 2.3 | 2.9 |
| Pulp—hydrolyzed | 0.98 | 1.5 | 2.3 | 1.32 | 0.9 | 0.7 | 2.6 |
| Spent liquor—$H_2SO_4$-hydrolyzed | 1.53 | 1.2 | 1.4 | 0.94 | 2.5 | 2.9 | 9.4 |

[a] The % ether extract is on the basis of the dry weight of solids or material.
[b] The % vanillin and all other compounds is on the basis of the ether extract for the particular experiment.
[c] The ratio of syringaldehyde to vanillin is on the molar basis.

A sample of the original *P. tremuloides* chips ground to sawdust contained 3.6% moisture.

The original wood, the spent liquor, the washings, and the pulp were each hydrolyzed with sodium hydroxide as described above. The alkaline mixtures were acidified and extracted with ether. The ether solutions were dried and concentrated. These concentrated ether solutions were analyzed quantitatively for vanillin, syringaldehyde, vanillic acid, syringic acid, and *p*-hydroxybenzoic acid as described above. Data for these experiments are given in Table II which also includes similar data for the ether extract of the spent liquor before hydrolysis and after sulfuric acid hydrolysis.

The material balance for known compounds in this study is given for the original 600 g. of ovendry wood in Table III.

Table III. Known Compound Balance for Neutral Sulfite Semichemical Cook of Aspen

| | Vanillin | | Syringaldehyde | | Vanillic acid | | Syringic acid | | p-Hydroxybenzoic acid | |
|---|---|---|---|---|---|---|---|---|---|---|
| | mg. | %[a] | mg. | % | mg. | % | mg. | % | mg. | % |
| Total compound after hydrolysis of original sawdust | 218.4 | | 294.0 | | 205.8 | | 226.8 | | 2133.6 | |
| Spent liquor—hydrolyzed | 164.2[b] | 75.2 | 264.6 | 90.0 | 191.2 | 57.9 | 131.8 | 58.1 | 310.7 | 14.6 |
| Washings—hydrolyzed | 53.0 | 24.2 | 113.0 | 38.4 | 42.5 | 20.7 | 60.0 | 26.5 | 75.5 | 3.5 |
| Pulp—hydrolyzed | 48.4 | 22.2 | 76.8 | 26.1 | 29.4 | 14.3 | 21.7 | 9.6 | 83.5 | 3.9 |
| Total compound recovered from hydrolyzed fractions after neutral sulfite semichemical cook | 265.6 | 121.6 | 454.4 | 154.5 | 191.1 | 92.9 | 213.5 | 94.2 | 469.7 | 22.0 |
| Spent liquor—$H_2SO_4$-hydrolyzed | 40.4 | 18.5 | 45.5 | 15.5 | 83.3 | 40.5 | 96.0 | 42.3 | 308.0 | 14.4 |

[a] The % values reported are based on the amount of the particular compound determined in the original 600 g. of sawdust after hydrolysis.
[b] Weight figures given in the table are calculated to 600 g. of starting material.

The data of Tables II and III indicate that the conditions of a neutral sulfite semichemical cook modify or transform the *p*-hydroxybenzoic acid present in the original aspenwood so that it no longer can be liberated as such by alkaline boiling. Although possible, it is very improbable that the *p*-hydroxybenzoic acid is actually destroyed by the conditions of the cook.

It is interesting to note in this study that the vanillin and syringaldehyde recoveries are actually increased by the neutral sulfite semichemical cook, and the vanillic and syringic acid are essentially unchanged. The sulfuric acid hydrolysis apparently liberates just as much *p*-hydroxybenzoic acid as does the alkaline hydrolysis after the neutral sulfite semichemical cook. These data suggest that the conditions of the cook might liberate *p*-hydroxybenzoic acid linked in the wood by nonglycosidic bonds, and then modify the liberated free acid so that it can no longer be isolated or determined as such. On the other hand, the *p*-hydroxybenzoic acid held in the wood by glycosidic bonds would be protected from the action of the cooking liquor and would be liberated only after subsequent boiling with sulfuric acid or with sodium hydroxide solutions. Although glycosidic linkages are normally stable toward alkali, other work in our laboratories on the extractives of aspenwood have indicated that *p*-hydroxybenzoic acid is liberated from carbohydrate materials by alkaline boiling.

## KNOWN COMPOUND BALANCES ON AN ASPEN KRAFT COOK

The above experiment on an aspen neutral sulfite semichemical cook led to similar experiments on the effect of other pulping processes on the known compounds obtainable from quaking aspen.

A sample of 9959 g. of *P. tremuloides* chips containing 5738 g. of ovendry wood and 4221 g. of moisture was pulped in a laboratory digester with a representative kraft cooking liquor to give 3028 g. of pulp on the ovendry basis and 31,877 g. of spent liquor and washings containing 4144 g. of total solids. The spent liquor from this kraft cook was processed in three different manners as follows:

1. The liquor was acidified with dilute sulfuric acid and continuously extracted with ether for 24 hr. in the air-agitated liquid-liquid extractor.

2. The liquor was treated with 10 g. of sodium hydroxide and boiled under reflux for 8 hr. The alkaline solution was then acidified with sulfuric acid and extracted with ether as noted under 1.

3. The liquor was made strongly acid by adding 300 g. of 50% sulfuric acid. The resulting mixture was boiled under reflux for 8 hr. and cooled. The cooled solution was extracted with ether as in 1.

In each experiment 615 g. of liquor containing 80 g. of solids were employed. The ether extracts from each of the above experiments were processed as before for the quantitative determination of all known compounds. These data are given in Table IV.

It was at this time in our laboratory that we found that *P. tremuloides* also yielded small amounts of *p*-hydroxybenzaldehyde and *p*-coumaric acid upon alkaline hydrolysis (*3*). Furthermore, it was found that the solvent system employed for the separation of vanillin and syringaldehyde for quantitative analysis did not separate vanillin from *p*-hydroxybenzaldehyde, and therefore, vanillin values reported in earlier studies were somewhat in error. In the present study, the developer

**Table IV. Known Compound Data for Kraft Cook of Aspenwood**

| | *Black liquor direct* | *Black liquor NaOH-treated* | *Black liquor $H_2SO_4$-treated* |
|---|---|---|---|
| Ether extract, %[a] | 10.98 | 5.3 | 6.1 |
| Vanillin, %[b] | 0.8 | 1.4 | 1.4 |
| Syringaldehyde, % | 2.1 | 3.6 | 4.1 |
| *p*-Hydroxybenzaldehyde, % | 0.3 | 0.5 | 0.4 |
| Vanillic acid, % | 1.2 | 1.8 | 2.1 |
| Syringic acid, % | 1.7 | 2.1 | 2.3 |
| *p*-Hydroxybenzoic acid, % | 4.2 | 8.1 | 11.8 |
| *p*-Coumaric acid, % | 0.0 | 0.0 | 0.0 |

[a] The % of ether extract is on the basis of the 80 g. of solids in each experiment.
[b] The % of vanillin and all other compounds is on the basis of the ether extract of the particular experiment.

employed was 6:1:1 heptane-*n*-butyl ether-water, and this developer separated all three aldehydes satisfactorily. Data for *p*-hydroxybenzaldehyde and *p*-coumaric acid are included in Table IV.

The data of Table IV have been recalculated to the total black liquor from the original 9959 g. of air-dried wood used in the kraft cook. These data are shown in Table V and are compared with similar data obtained from the alkaline hydrolysis of a sample of the same batch of *P. tremuloides* calculated to the same original weight.

The data of Table V prove that the kraft cooking process, when applied to aspenwood, actually produces substantial amounts of the aldehydes, vanillin, and syringaldehyde. It is interesting to note that subsequent alkaline boiling reduces the amount of these aldehydes in the black liquor, whereas subsequent boiling in sulfuric acid increases the yields. The kraft process also increases the amounts of vanillic and syringic acids, but *p*-coumaric acid is destroyed completely. Probably some of this is converted to *p*-hydroxybenzoic acid during the cook.

The kraft cook produced about the same amount of *p*-hydroxybenzoic acid from aspenwood as did an alkaline boil. Subsequent alkaline boiling caused a reduction in this amount, but subsequent acid boiling caused a substantial increase in the total *p*-hydroxybenzoic acid recoverable from the kraft black liquor. Again, it is possible that glycosidic linkages surviving the kraft cook were hydrolyzed by the sulfuric acid boil to yield more of the *p*-hydroxybenzoic acid. The decrease in the *p*-hydroxybenzoic acid yield after alkaline boiling cannot be explained.

## KNOWN COMPOUND BALANCES ON AN ACID SULFITE COOK OF ASPEN

A sample of *P. tremuloides* chips weighing 1046 g. and containing 600 g. of ovendry wood was pulped with a sodium-base acid sulfite liquor in a 6-1. stainless steel digester exactly as described earlier (*1*). As before, no relief was allowed, and the pulping mixture was cooled rapidly in the digester before the digester was opened. The pulp was squeezed as dry as possible, washed twice with water, and filtered each time. The combined filtrate and washing were concentrated under reduced pressure to give a liquor containing 383 g. of solids in an 8% solution. The pulp weighed 1310 g. and contained 364 g. of ovendry pulp.

Aliquots of the concentrated spent liquor were processed directly and after alkaline hydrolysis. In addition, the pulp was subjected to alkaline hydrolysis and processed like the other samples. Data for these experiments are given in Table VI.

It is interesting to note that except for *p*-hydroxybenzoic acid, all compounds occur in greater percentage in the ether extract from the hydrolysis of the pulp than in the ether extract from the hydrolysis of the spent liquor.

Again, the data of Table VI have been recalculated to the 1046 g. of airdry (600 g. ovendry) *P. tremuloides* employed in the original acid sulfite cook. These recalculated data are compared in Table VII with similar data obtained drom the alkaline hydrolysis of a sample of the same batch of *P. tremuloides* calculated to the same weight. (This is the same wood reported in Table V.)

The data of Table VII demonstrate several interesting facts.

1. Acid sulfite cooking of *P. tremuloides* increases the amount of vanillin and syringaldehyde obtainable by alkaline hydrolysis. This fact was to be expected, because for many years it was assumed by most lignin investigators that only in the form of its sulfonate would

**Table V. Recovery of Known Compounds from Aspen After a Kraft Cook**

| | *Aspenwood hydrolyzed, g.*[a] | *Black liquor direct, g.* | *Black liquor NaOH-treated, g.* | *Black liquor $H_2SO_4$-treated, g.* |
|---|---|---|---|---|
| Vanillin | 1.32 | 3.47 (263)[b] | 3.13 (237) | 3.60 (273) |
| Syringaldehyde | 1.99 | 9.56 (479) | 7.90 (396) | 10.26 (514) |
| *p*-Hydroxybenzaldehyde | 1.72 | 1.19 (69) | 1.09 (63) | 0.91 (53) |
| Vanillic acid | 2.21 | 6.68 (302) | 3.94 (178) | 5.39 (244) |
| Syringic acid | 1.98 | 9.51 (480) | 4.61 (233) | 5.75 (290) |
| *p*-Hydroxybenzoic acid | 22.59 | 23.75 (105) | 17.79 (79) | 29.79 (132) |
| *p*-Coumaric acid | 5.25 | 0.0 | 0.0 | 0.0 |

[a] Weights reported are on the basis of 9959 g. of airdry (5738 g. ovendry) wood.
[b] Values in parentheses are percentages based on the amount of the particular compound determined in the original aspenwood after hydrolysis—the values in column 1.

**Table VI. Known Compound Data for Acid Sulfite Cook of Aspenwood**

| | *Spent liquor direct* | *Spent liquor NaOH-treated* | *Pulp NaOH-treated* |
|---|---|---|---|
| Ether extract, %[a] | 1.0 | 2.3 | 0.7 |
| Vanillin, %[b] | 0.3 | 1.6 | 2.0 |
| Syringaldehyde, % | 0.5 | 2.6 | 3.6 |
| *p*-Hydroxybenzaldehyde, % | 0.3 | 0.6 | 2.0 |
| Vanillic acid, % | 0.6 | 1.4 | 4.9 |
| Syringic acid, % | 1.7 | 2.0 | 3.1 |
| *p*-Hydroxybenzoic acid, % | 21.1 | 25.1 | 16.9 |
| *p*-Coumaric acid, % | 0.2 | 0.6 | 4.9 |

[a] The % of ether extract is on the basis of the solids in each experiment.
[b] The % of vanillin and all other compounds is on the basis of the ether extract of the particular experiment.

**Table VII. Recovery of Known Compounds from Aspen After an Acid Sulfite Cook**

| | *Aspenwood hydrolyzed, mg.*[a] | *Spent liquor direct, mg.* | *Spent liquor NaOH-treated, mg.* | *Pulp NaOH-treated, mg.* | *Total, %*[b] |
|---|---|---|---|---|---|
| Vanillin | 138 | 12 (9)[c] | 146 (106) | 49 (36) | 142 |
| Syringaldehyde | 198 | 18 (9) | 233 (118) | 90 (46) | 164 |
| *p*-Hydroxybenzaldehyde | 180 | 12 (7) | 55 (31) | 50 (28) | 59 |
| Vanillic acid | 231 | 22 (9) | 125 (54) | 122 (53) | 107 |
| Syringic acid | 207 | 66 (32) | 178 (86) | 77 (37) | 123 |
| *p*-Hydroxybenzoic acid | 2676 | 562 (21) | 2162 (81) | 424 (16) | 97 |
| *p*-Coumaric acid | 549 | 10 (2) | 65 (12) | 122 (22) | 34 |

[a] Weights reported are on the basis of 1046 g. airdry (600 g. ovendry) wood.
[b] Percentages reported in this column are the sums of percentages obtained from the alkali-hydrolyzed spent liquor and the alkali-hydrolyzed pulp.
[c] Values in parentheses are percentages based on the amount of the particular compound determined in the original aspenwood after hydrolysis—the values in column 1.

Table VIII. Recovery of Known Compounds from Aspen After a Soda Cook

| | *Soda cook, %*[a] | *Aspenwood hydrolyzed, mg*[b] | *Soda cook, mg*[c] |
|---|---|---|---|
| Ether extract | 8.38 | | |
| Vanillin | 1.4 | 23.0 | 114.0 (475)[c] |
| Syringaldehyde | 3.8 | 33.0 | 317.0 (960) |
| *p*-Hydroxybenzaldehyde | 0.7 | 30.0 | 57.5 (192) |
| Vanillic acid | 1.0 | 38.5 | 81.0 (210) |
| Syringic acid | 1.4 | 34.5 | 118.0 (342) |
| *p*-Hydroxybenzoic acid | 4.6 | 446.0 | 338.0 (87) |
| *p*-Coumaric acid | 0.0 | 91.5 | 0.0 |

[a] The % ether extract is on the basis of the solids in each experiment. The % of vanillin and all other compounds is on the basis of the ether extract.
[c] Weights reported are on the basis of 100 g. of wood originally employed.
[b] Values in parentheses are percentages based on the amount of the particular compound determined in the original aspenwood after hydrolysis with alkali at atmospheric pressure—values in column 2.

lignin yield vanillin and syringaldehyde by alkaline hydrolysis (*8*).

2. The yield of syringic acid increased considerably, but the yields of vanillic and *p*-hydroxybenzoic acids remained essentially unchanged.

3. Yields of *p*-hydroxybenzaldehyde and of *p*-coumaric acid decreased considerably after a sulfite cook.

4. Except for syringic acid and *p*-hydroxybenzoic acid, all of the compounds studied occur *per se* in the spent liquor in only minute amounts.

5. The preponderance of vanillin- and syringaldehyde-yielding moieties are found in the spent liquor from the acid sulfite cook, whereas a high percentage of the *p*-hydroxybenzaldehyde-, vanillic acid-, syringic acid-, and *p*-coumaric acid-yielding moieties remain with the pulp. The moieties associated with the pulp may be absorbed materials or may be materials still linked to lignin remaining in the fiber.

6. Acid sulfite pulping apparently causes a slight increase of syringaldehyde-yielding moieties over vanillin-yielding moieties.

7. The extract of the alkaline-hydrolyzed spent liquor yielded a new material which gave an acid reaction, but which has not been identified as yet. From the various chromatograms it appears that this unidentified acid is present in substantial amounts.

## KNOWN COMPOUNDS FROM A SODA COOK OF ASPEN

Authentic *P. tremuloides* was subjected to a laboratory soda cook at 170°C. for 3 hr. and the black liquor and washings were processed in accordance with procedures already outlined. The qualitative and quantitative data obtained were compared with those obtained for a standard alkaline hydrolysis of the same sample of *P. tremuloides* at atmospheric pressure. Results are given in Table VIII. The wood employed in this experiment was from the same bolt used for the kraft and acid sulpfite cooks reported in Tables V and VII.

The data of Table VIII indicate that the yields of all compounds except *p*-hydroxybenzoic acid and *p*-coumaric acid are increased greatly by hydrolyzing at 170° under the conditions of the soda cook. Apparently, all *p*-hydroxybenzoic acid-yielding materials in the wood are hydrolyzed under the conditions of the atmospheric boil. This indicates that *p*-hydroxybenzoic acid linkages are labile and require only hydrolytic conditions for cleavage. On the other hand, the other compounds determined require the drastic conditions of the 170° soda cook for maximun yield under only hydrolyzing conditions indicating much stronger linkages such as carbon-carbon bonds. The drastic conditions of the soda cook destroy *p*-coumaric acid which is stable under the conditions of the alkaline boil at atmospheric pressure.

Table IX. Analyses of Liquors I and V After Hydrolysis with Alkali

| | *Liquor I, %* | *Liquor V, %* |
|---|---|---|
| Ether extract | 6.8[a] | 5.9[a] |
| Vanillin | 1.7[b] | 3.4 |
| Springaldehyde | 1.5 | 2.8 |
| *p*-Hydroxybenzaldehyde | 0.6 | 0.8 |
| Vanillic acid | 0.8 | 1.7 |
| Syringic acid | 0.8 | 1.7 |
| *p*-Hydroxybenzoic acid | 7.1 | 15.0 |
| *p*-Coumaric acid | 0.9 | 1.8 |

[a] The % of ether extract is on the basis of the original 80 g. of solids in each experiment.
[b] The % of vanillin and all the other compounds is on the basis of the ether extract for the particular experiment.

## RE-EVALUATION OF ASPEN SPENT SULFITE LIQUORS

The indication during the course of this study that earlier reported yields for vanillin were probably in slight error due to the presence of *p*-hydroxybenzaldehyde in the hydrolyzed liquors led to a reinvestgation of the original concentrated liquor I. At the same time another liquor, liquor V, was studied. Liquor V was a laboratory-concentrated liquor prepared from a *Torulopsis utilis*-fermented ammonia-base spent sulfite liquor from the cooking of mixed peeled aspens and obtained from the Charmin Paper Products Co. in November, 1956. The concentrated liquor contained 31.83 g. of solids per 100 g. of liquor, and the solids contained 10.76% methoxyl and 1.80% total sugars.

Liquors I and V were subjected to alkaline hydrolysis at atmospheric pressure, and the resulting mixtures analyzed as before. Qualitative paper chromatograms indicated the same compounds noted before. Quantitative data are given in Table IX.

From the data of Table IX it is apparent that liquor V gave substantially higher percentages in the ether extract after hydrolysis of vanillin, syringaldehyde, and especially *p*-hydroxybenzoic acid. This may have been due to changes caused by fermentation, to a possible difference in cooks, to a possible difference in individual wood species comprising the furnish of the cooks, to possible ether-soluble alkaline reaction products of the carbohydrates in liquor I, or to any combination of these.

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# Development of a Rate Expression for Kraft Pulping Reactions

CHARLES W. CARROLL

**Motivated primarily by the need of a mathematical representation of the cooking operation in the economic optimization of a kraft pulping process, a rate expression, appropriate to this work, was developed. A main feature of this development is a quantitative accounting for the decreasing alkali concentration during a cook. The developed rate expression, which has been experimentally verified, predicts total time for a cook to within ±0.3% (95% confidence limits are ±1 min.) as a function of initial temperature, time-up-to-temperature, maximum temperature, initial concentration, chemical-to-wood ratio, permanganate number, and yield. The equation can be used for the system studied only within certain rather broad limitations. The most important of these seems to be that sulfide concentration during the cook must always be high enough to assure that the rate-controlling reaction involves sodium hydroxide rather than sodium sulfide or a derivative thereof. Additional work, perhaps of a similar nature, will be necessary to quantitatively describe the kinetics over the full range of kraft pulping conditions (especially the presently employed commercial range).**

THE importance of developing quantitative interrelationships among pulping variables, especially the kraft cooking variables, has long been appreciated. Such interrelationships would provide for better understanding of actual cooking reactions and some insight into the development of pulp quality characteristics. In addition, these expressions would allow for a reduction in the labor involved in pulping experimentation, and could provide information helpful in making better mill-operating decisions.

This paper describes one phase of a comprehensive economic balance of a hypothetical but realistic kraft pulping process (*1*). In this economic balance it was desirable to represent, quantitatively, all the related operations of the process so that the conditions maximizing the system's profitability could be mathematically determined. Having a rate expression interrelating the cooking variables thus makes it possible to quantitatively describe the digester operation along with the washer, evaporator, causticizing, and other related operations in the pulping system.

An investigation of the literature revealed the lack of any generally useful pulping rate expression. However, there seemed to be evidence encouraging belief in the existence of such expressions and hinting at how one might be derived. Consequently, a study was undertaken wherein a rate expression suitable for the purposes of the economic optimization referred to above was developed and experimentally verified.

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## NOMENCLATURE

| | | |
|---|---|---|
| A.A. | = | active alkali: NaOH + $Na_2S$ each expressed as g. $Na_2O$ |
| $c$ | = | concn. presumably of NaOH |
| $c_{av}$ | = | av. A.A. concn. (g./l.) according to equation (11) |
| $c_{av}'$ | = | av. A.A. concn. (g./l.) according to equation (7) |
| $c_i$ | = | initial A.A. concn., g./l. |
| $c_w$ | = | initial A.A.-to-wood ratio, g./g. |
| $K$ no. | = | permanganate number, 40-ml. basis |
| $L$ | = | % lignin in pulp at any time, $t$, based on original ovendry (o.d.) wood |
| $L_f$ | = | final % lignin in pulp, based on original o.d. wood |
| $L_i$ | = | initial % lignin in wood, based on o.d. wood |
| $l/w$ | = | liquor-to-wood ratio, ml./g. |
| $S$ | = | sulfidity: (g. $Na_2S$ as $Na_2O$)100/A.A., % |
| $T$ | = | temp. at any time, $t$, °Abs. |
| $T_m$ | = | max. temp. °Abs. |
| $T_0$ | = | initial temp., °Abs. |
| $t$ | = | time |
| $t_t$ | = | total time of a cook, min. |
| $t_u$ | = | time-up-to-temp., min. |
| $V_L$ | = | total liquor volume, ml. |
| $w$ | = | original o.d. wood charge, g. |
| $Y$ | = | total pulp yield, % o.d. pulp based on o.d. wood |
| $\alpha_1$ | = | % "difficultly removed" lignin based on original o.d. wood |
| $\alpha_2''$, $\alpha_2'$, $\alpha_2$ | = | apparent rate constants when NaOH is controlling |
| $\alpha_3$ | = | constant related to apparent energy of activation for gross pulping reaction |
| $\alpha_4$, $\alpha_5$, $\alpha_6$, $\alpha_7$, $\alpha_8$ | = | constants related to A.A. consumption |

## DEVELOPMENT OF THE RATE EXPRESSION

The formulation of a pulping system model for the economic optimization required the development of a cooking rate expression for the production of an unbleached grade of spruce kraft pulp. It was necessary that the expression involve all the important kraft cooking variables over a reasonably wide range of cooking conditions.

For a given kraft pulping system, the cooking variables usually considered as important are: initial temperature ($T_0$); time-up-to-temperature ($t_u$); maximum temperature ($T_m$); total time of cook ($i_t$); sulfidity ($S$); and two of: initial active alkali concentration ($c_i$), initial active alkali-to-wood ratio ($c_w$), and liquor-to-wood ratio ($l/w$). In addition, the time-temperature schedule during the cook must be known.

Kraft pulping studies (*2*) have been made where the concentration, $c$, of sodium hydroxide (presumed to be the rate-limiting constituent) has been held effectively constant during the reaction by means of very high chemical-to-wood ratios. These studies indicate that the "apparent" (*3*, *4*) rate of delignification, when cooking at constant temperature and to yields corresponding to those for unbleached grades of pulp, can be represented by

$$\frac{dL}{dt} = \alpha_2''c(L - \alpha_1) \qquad (1)$$

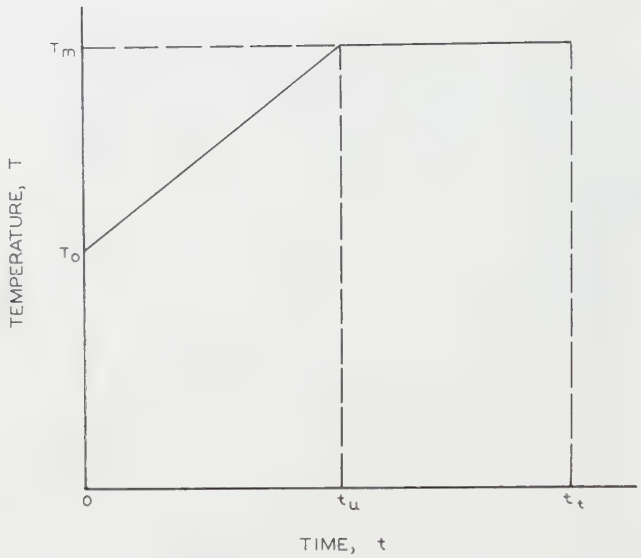


*Fig. 1. Temperature-time relationship in hypothetical mill*

or

$$\frac{dL}{L - \alpha_1} = \alpha_2'' c\, dt \qquad (2)$$

where $L$ represents the percentage lignin based on the original o.d. wood at any time, $t$. The constant, $\alpha_1$, appears to represent "difficultly removed lignin" (*2, 4–6*). There may be some physical and/or chemical basis for this. In any case, $\alpha_1$, allows for a better fit of the data.

The rate of delignification is, by equation (1), proportional to the concentration, a phenomenon noted more or less qualitatively elsewhere (*4, 6–8*).

#### *Application of the Arrhenius Equation*

The $\alpha_2''$ (the apparent rate constant) of equations (1) and (2) depends on the temperature, $T$. The general applicability of the Arrhenius equation to nearly all kinds of chemical reactions is well known (*9*). Many investigators have suggested or demonstrated the usefulness of the Arrhenius equation in pulping reactions, e.g., (*2, 4, 5, 7, 10*). Vroom (*10*), in particular, has shown the broad applicability of this equation to kraft pulping reactions. While Vroom was not interested in absolute reaction rates, the Arrhenius equation can be used to build into equation (2) an appropriate time-temperature relationship, resulting in equation (3).

$$\frac{dL}{L - \alpha_1} = \alpha_2'(e^{-\alpha_3/T}) c\, dt \qquad (3)$$

Here $\alpha_2'$ is the product of $\alpha_2''$ of equation (2) and the *apparent* "collision frequency factor" of the Arrhenius equation. Constant $\alpha_3$, is related to the *apparent* energy of activation for the gross pulping reaction.

Groups of cooks studied in Vroom's work can be considered as having varied only in temperature and time in reaching the same final degree of pulping. Therefore, chemical consumption, and thus average concentration during any given group of cooks, can be considered to have been effectively constant.

The integration of equation (3) at constant concentration requires temperatures to be expressed as functions of time. If a cooking schedule is followed, this relationship is known; or it can be observed or predicted.

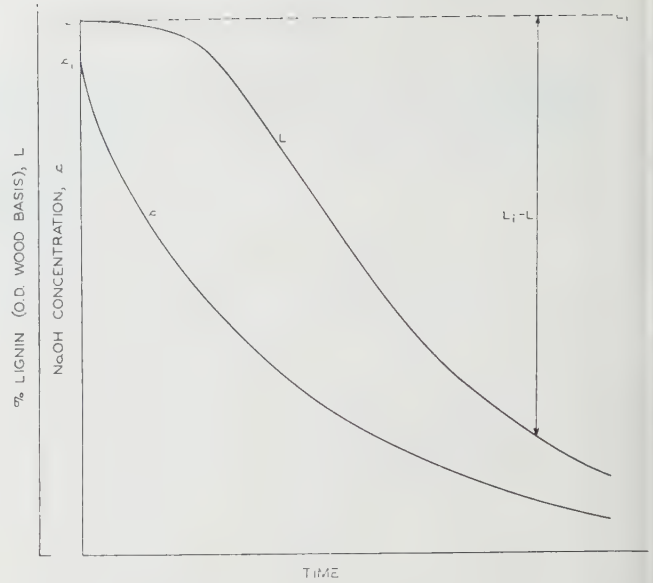


*Fig. 2. Qualitative interrelationships between NaOH concentration and time, and lignin and time*

In the hypothetical mill considered in (*1*), temperature rise is straight-line during the time-up period, and thereafter the temperature is constant (see Fig. 1). The time-temperature relationships for these two periods are:

$$T = T_0 + t(T_m - T_0)/t_u, \qquad 0 \le t \le t_u \qquad (4)$$

and

$$T = T_m, \qquad t_u \le t \le t_t \qquad (5)$$

Equations (4) and (5) allow equation (3) to be integrated at constant concentration.

#### *Variation in Concentration During the Cook*

For any industrially realistic kraft cooking operation, though, concentration varies significantly during the cook. This is because continuous consumption of cooking chemicals leaves noticeable deficits in the limited amounts of chemical which can be economically

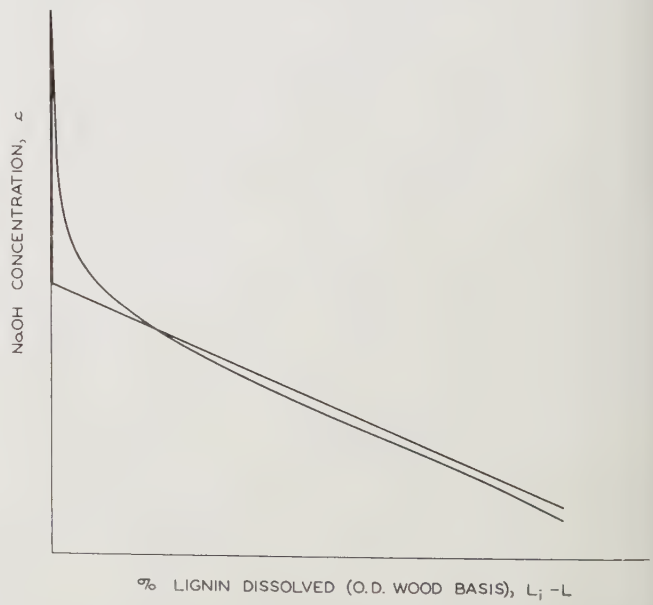


*Fig. 3. Qualitative interrelationship between NaOH concentration and lignin dissolved (curved line, actual, from Fig. 2; straight lines, approximate)*

present. The concentration at any time during a cook depends not only on initial concentration, $c_i$, and the chemical consumption, but also on $c_w$, the chemical-to-wood ratio. The interrelationship between $c_i$ and $c_w$ has been repeatedly emphasized in connection with the qualitative concept of a "mean concentration" during a cook (*6, 8, 11*).

In order to apply equation (3) to the industrially realistic situation of varying concentration, it is necessary to know how concentration changes with time or lignin content throughout a cook. From Hagglund and Hedlund's work (*12*), the lignin content of the pulp, $L$, and from Borlew and Pascoe's work (*13*), the NaOH concentration, $c$, can each be plotted, qualitatively, against time, $t$ (Fig. 2). Then NaOH concentration and pulp lignin content (or lignin dissolved) can be related by plotting one against the other at the same times (the curve in Fig. 3).

Initially in a kraft cook, as has long been known, considerable NaOH is consumed almost immediately, due to extensive reaction with carbohydrates at temperatures at which lignin is almost unreactive. Thereafter, the decrease in NaOH slows and falls nearly linearly with the lignin remaining in the pulp. This is consistent with observations that NaOH consumption is directly proportional to wood dissolved (*14*), while wood dissolved is directly proportional to lignin dissolved (*15*) during this stage of soda cooks. [In Fig. 3, lignin dissolved is $(L_i - L)w/100$, where $L_i$ is the initial lignin content of the wood and $L$ is the pulp lignin content at time, $t$, each expressed as a percentage based on original o.d. wood weight. The o.d. wood charge is $w$.]

Figure 3 shows that this typical change in NaOH concentration during delignification can be very well approximated by an initially large, *immediate* consumption of NaOH proportional to the carbohydrates (wood) present, $\alpha_4 w$, followed by a linear decrease (displaying some characteristic slope, $\alpha_5$) as lignin is dissolved out of the pulp. Thus, concentration at any time during the cook can be expressed as

$$c = c_i - \frac{\alpha_4 w + \alpha_5(L_i - L)w}{V_L}$$

or

$$c = c_i - \frac{c_i}{c_w}\left[\alpha_4 + \alpha_5(L_i - L)\right] \qquad (6)$$

where $V_L$ is the total liquor volume.

Equation (6), along with equations (4) and (5) can be substituted into equation (3) and the latter then integrated. However, a useful simplification can be made. This is to consider an *average concentration*, $C_{av.}'$, which can be thought of as that concentration which, if maintained constant during the cook, would produce the same effects as a varying concentration initially at $c_i$. The equation for $c_{av.}'$ has the same form as equation (6) with $L$ replaced by $L_f$ (final pulp lignin content). But since all the cooks in the hypothetical mill considered in the economic optimization of (*1*) are to the *same* final pulp lignin content, the new equation defining $c_{av.}'$ can be written:

$$c_{av.}' = c_i - \alpha_6 \frac{c_i}{c_w} \qquad (7)$$

Equation (7) would be expected to be applicable over a limited range of $L_f$ (or permanganate numbers) since the slope, $\alpha_5$, in equation (6) is probably relatively small (see Discussion).

### *The Integrated Rate Expression*

Substituting equation (7), along with equations (4) and (5), into equation (3) and integrating between appropriate limits using, where necessary, suitable approximations, one obtains:

$$t_t = \frac{\ln \dfrac{L_f - \alpha_1}{L_i - \alpha_1}}{\alpha_2'(e^{-\alpha_3/T_m})\left(c_i - \alpha_6 \dfrac{c_i}{c_w}\right)} + t_u\left[1 - \frac{(T_m)^2}{\alpha_3(T_m - T_0)}\right] \qquad (8)$$

The integration is developed in (*1*). In the integration, $c_{av.}'$ is treated as a constant concentration since, under the conditions assumed, it depends only on initial conditions: $c_i$ and $c_w$ [see equation (7)].

### *Estimation of $L_f$ from K no. and Y*

The final pulp lignin content, $L_f$, can be estimated from the permanganate number ($K$ no.) and total unscreened pulp yield ($Y$) by means of equation (9):

$$L_f = [(K \text{ no.})(0.292) - 2.53]\frac{Y}{100} \qquad (9)$$

This equation was derived by combining Borlew and Keller's work (*16*) showing a general linear relationship between Roe chlorine number and lignin content,* and a linear approximation based on Hart and Strapp's data (*18*), wherein $K$ no. and Roe chlorine number can be related for spruce pulp cooked to a $K$ no. of around 25.† (This is the kind of pulp considered in the economic optimization.)

Substituting equation (9) into equation (8) gives

$$t_t = \frac{\ln \dfrac{[(K \text{ no.})(0.292) - 2.53]\dfrac{Y}{100} - \alpha_1}{L_i - \alpha_1}}{\alpha_2'(e^{-\alpha_3/T_m})\left(c_i - \alpha_6 \dfrac{c_i}{c_w}\right)} + t_u\left[1 - \frac{(T_m)^2}{\alpha_3(T_m - T_0)}\right] \qquad (10)$$

Equation (10) was tested with certain of Hart and Strapp's comprehensive kraft pulping data (*18*). In their work, the sulfidity was constant at 33% while the liquor-to-wood ratio was fixed at 3.5 ml. per g. Time-temperature relationships were straight-line and known. There was evidence enough that with very careful control and sufficient data, equation (10) might well prove to be the integrated rate expression desired. However, experimental results would, in addition to verifying equation (10), have to indicate how sulfidity (or the concept of "effective alkali") might be incorporated. Consequently, a laboratory investigation was undertaken with these purposes in mind.

## EXPERIMENTAL VERIFICATION OF THE RATE EQUATION

A number of carefully controlled cooks were made under conditions designed to verify equation (10) and to provide information as to how sulfidity might be

* $L_5$ = [(0.811) (Roe chlorine number) − 0.110]$Y$/100; a similar expression, also for spruce, and derived more recently appears in (*17*).

† Roe chlorine number = 0.360 ($K$ no.) − 2.98.

incorporated. The experimental design involved the following ranges of cooking variables:

| | |
|---|---|
| $l/w$, ml./g. | 6.736 to 15.459 |
| $c_i$, g. A.A./l. | 26.72 to 57.90 |
| $c_w$, g. A.A./g. | 0.1800 to 0.6885 |
| $S$, % | 25.0 to 60.0 |
| $Na_2S$ concn., mol./l. | 14.22 to 46.69 |
| Max. temp., °C. | 160 and 170 |
| Init. temp., °C. | 31.0 to 35.0 |
| $t_u$, min. | 60 and 90 |

***Experimental Procedure***

A sufficient amount of sprucewood was collected from the woodyard of the Interlake Division of the Consolidated Water Power & Paper Co., Appleton, Wis. This wood was then chipped in The Institute of Paper Chemistry chipper, and the chips, after being mixed thoroughly, were moisture-sampled while a large number of storage bags were progressively filled with a given wet (and therefore o.d.) weight of chips. The bags of chips were stored in a cold room until immediately before use.

The active cooking chemicals used were commercial flake sodium hydroxide and "purified crystals" of sodium sulfide. Solutions of each of these basic kraft cooking chemicals were made up periodically, stored separately, and frequently titrated so as to monitor any chemical change. The sodium hydroxide (and sodium carbonate) concentrations were determined in triplicate by the standard hydrochloric acid double end-point titration, using phenolphthalein and methyl orange indicators. Only a trace of sodium carbonate was ever present. The sodium sulfide concentration was determined in quadruplicate by TAPPI Standard T 624 m-44, modified by using slightly different aliquots and a constant 10 ml. of 4 $N$ $H_2SO_4$ in place of acetic acid. It was assumed that sulfite and thiosulfate were present in only negligible amounts.

Immediately before a given cook, required amounts of each stock solution were drawn off, mixed, and diluted to the desired total volume, $V_L$. The desired active alkali concentration ($c_i$) and sulfidity were obtained by considering the stock solution concentrations, the o.d. wood charge ($w$), the required liquor-to-wood ratio, and the water present in the chips. In order to provide initial chip coverage when the basket of chips was in position in the digester, a liquor-to-wood ratio [$V_L$(ml.) per $w$(g.)] of at least about 6.7 ml. per g. was required.

The chips, which were 85.80% dry, were cooked in a basket in a conventional, indirect-heated, laboratory digester. Very rigid temperature-time control was maintained during the cooks. A typical temperature-time record is shown in Fig. 4. Virtually complete relief was provided at 100°C. and the digester was blown at full pressure. The blow was accomplished in a matter of seconds. The temperature of the chip mass dropped to below 120°C. in less than 30 sec. following a blow. During the cook, the temperature read was that of the liquor stream coming into the top of the digester from the heat exchanger.

The hot pulp was brush-refined (at a "loose" 0.003 in.) in a Sprout-Waldron laboratory refiner to provide good disintegration of the pulped chips with a minimum of mechanical damage to the fibers. The refined pulp was then thoroughly washed and centrifuged. Yields were determined in quadruplicate. Yield moisture samples were oven dried in a 105°C. oven for 2 days The standard deviation of yield determinations was about 0.13%.

Following yield determination, a representative portion of the pulp was screened (screenings were negligible) in preparation for permanganate number determinations. An improved sampling technique allowed for considerably increased precision and accuracy in the permanganate number procedure. This improved technique involved the *simultaneous* filling of seven 1000-ml. graduate cylinders each with a slurry volume expected to give (based on duplicate consistency samples) 1 g. o.d. pulp. Permanganate numbers were determined on four of these samples, randomly chosen, by use of the analytical procedure described in TAPPI Standard T 214 m-50. A 40-ml. basis was always used. The remaining three samples were used to estimate the o.d. weight of pulp *actually* present in the permanganate number determinations. The standard deviation in $K$ no. determinations was about 0.26, much better than could have been obtained using the conventional sampling technique with the same equipment.

***Data and Results***

The experimental data and calculated results are shown in Table I. Preliminary calculations indicated that for a good fit of the data, the expression for $c_{av.}'$. [equation (7)] needed the addition of an apparently empirical constant, $\alpha_8$, representing additional chemical consumption. For generality, the value of $\alpha_6$ in equation (7) was replaced by a new constant, $\alpha_7$. Equation (7) thus became equation (12:)

$$c_{av.} = c_i - \alpha_7 \frac{c_i}{c_w} - \alpha_8 \ddagger \qquad (11)$$

Using equation (11) instead of (7), equation (10) becomes equation (12):

$$t_t = \frac{\ln \dfrac{[(K \text{ no.})(0.292) - 2.53]\dfrac{Y}{100} - \alpha_1}{L_i - \alpha_1}}{\alpha_2'(e^{-\alpha_3/T_m})\left(c_i - \alpha_7 \dfrac{c_i}{c_w} - \alpha_8\right)} + t_u\left[1 - \frac{(T_m)^2}{\alpha_3(T_m - T_0)}\right] \qquad (12)$$

The values of "Calcd. $t_t$"in Table I were derived from equation (13), below. Equation (13) is equation(12) with "best-fit" values for the undetermined constants, along with the yield and $K$ no. actually occurring in the cooks. The initial lignin content of the wood, $L_t$, is taken to be 26% for the spruce chips used (see "Constants in the Rate Expression" in the Discussion). In effect, "Calcd. $t_t$" is "$t_t$ *predicted*" for the particular conditions and the expected yield and $K$ no. Equation (13), used to derive "Calcd. $t_t$" in Table I, is:

$$t_t = \frac{\ln \dfrac{[(K \text{ no.})(0.292) - 2.53]\dfrac{Y}{100} - 1.00}{25.00}}{(-5.22 \times 10^{-5})(e^{40-(16,100)/T_m})\left(c_i - (0.0663)\dfrac{c_i}{c_w} - 5.05\right)} + t_u\left[1 - \frac{(T_m)^2}{16{,}100(T_m - T_0)}\right] \qquad (13)$$

‡ Note: A $c_{av.}$ giving virtually as good a fit as equation (11) could have been expressed by other functional forms, such as $c_i = \gamma_1(c_i/c_w)^{\gamma_2}$ where $\gamma_1$ and $\gamma_2$ are "best-fit" constants. However, these seem no less empirical than equation (11). Consequently, equation (11) was used.

**Table I. Experimental Data and Calculated Results for Kraft Pulping Rate Expression**

| Cook | 1/w, ml./g. | ci, g. A.A./l. | cw, g. A.A./g. | S, % | $Na_2S$ concn., mol/l. | Max. temp., °C. | Init. temp., °C. | tu, min. | Y, % | K no. | $L_f$[a] | $-ln$[b] | e[c] | t[d] | $c_{av}$[e] | Calcd. $t_t$, min. | Act. $t_t$, min. | $\Delta f$ | % Error[g] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | 6.736 | 31.18 | 0.2100 | 33.0 | 0.1659 | 170.0 | 33.0 | 90.0 | 49.5 | 24.9 | 2.35 | 2.920 | 38.74 | 82.0 | 16.28 | 170.7 | 171.7 | −1.0 | −0.58 |
| 8 | 6.736 | 35.63 | 0.2400 | 33.0 | 0.1896 | 170.0 | 33.0 | 90.0 | 48.9 | 24.4 | 2.24 | 3.002 | 38.74 | 82.0 | 20.73 | 153.6 | 153.1 | 0.5 | 0.33 |
| 3 | 6.736 | 40.09 | 0.2700 | 33.0 | 0.2134 | 170.0 | 33.0 | 90.0 | 48.4 | 25.8 | 2.42 | 2.870 | 38.74 | 81.9 | 25.19 | 138.2 | 138.0 | 0.2 | 0.14 |
| 18 | 6.736 | 40.09 | 0.2700 | 33.0 | 0.2134 | 170.0 | 34.0 | 90.0 | 48.8 | 25.1 | 2.34 | 2.926 | 38.74 | 81.9 | 25.19 | 139.3 | 140.1 | −0.8 | −0.57 |
| 6 | 6.736 | 44.54 | 0.3000 | 33.0 | 0.2371 | 170.0 | 32.0 | 90.0 | 48.3 | 24.8 | 2.29 | 2.968 | 38.74 | 82.1 | 29.64 | 131.6 | 131.5 | 0.1 | 0.08 |
| 5 | 6.736 | 48.99 | 0.3300 | 33.0 | 0.2608 | 170.0 | 34.0 | 90.0 | 48.4 | 25.3 | 2.36 | 2.915 | 38.74 | 81.9 | 34.09 | 124.2 | 124.8 | −0.6 | −0.48 |
| 7 | 6.736 | 53.45 | 0.3600 | 33.0 | 0.2845 | 170.0 | 31.0 | 90.0 | 48.1 | 25.0 | 2.29 | 2.963 | 38.74 | 82.1 | 38.55 | 120.1 | 119.9 | 0.2 | 0.17 |
| 4 | 6.736 | 57.90 | 0.3900 | 33.0 | 0.3082 | 170.0 | 31.0 | 90.0 | 48.0 | 25.3 | 2.34 | 2.927 | 38.74 | 82.1 | 43.00 | 115.8 | 115.6 | 0.2 | 0.17 |
| 12 | 6.736 | 48.99 | 0.3300 | 40.0 | 0.3161 | 170.0 | 34.0 | 90.0 | 48.6 | 23.9 | 2.16 | 3.067 | 38.74 | 81.9 | 34.09 | 126.4 | 126.8 | −0.4 | −0.32 |
| 13 | 6.736 | 35.63 | 0.2400 | 60.0 | 0.3448 | 170.0 | 34.0 | 90.0 | 49.1 | 22.9 | 2.05 | 3.172 | 38.74 | 81.9 | 20.73 | 157.6 | 157.1 | 0.5 | 0.32 |
| 14 | 6.736 | 57.90 | 0.3900 | 50.0 | 0.4669 | 160.0 | 34.0 | 60.0 | 48.8 | 24.7 | 2.28 | 2.969 | 16.74 | 54.5 | 43.00 | 133.5 | 132.5 | 1.0 | 0.76 |
| 20 | 15.459 | 44.54 | 0.6885 | 33.0 | 0.2371 | 170.0 | 33.0 | 90.0 | 47.5 | 25.5 | 2.33 | 2.934 | 38.74 | 82.0 | 35.20 | 123.2 | 123.6 | −0.4 | −0.32 |
| 21 | 15.459 | 31.18 | 0.4820 | 33.0 | 0.1659 | 170.0 | 33.0 | 90.0 | 48.1 | 25.0 | 2.29 | 2.962 | 38.74 | 82.0 | 21.84 | 149.1 | 148.7 | 0.4 | 0.27 |
| 22 | 11.092 | 40.09 | 0.4447 | 33.0 | 0.2134 | 170.0 | 33.0 | 90.0 | 47.9 | 24.7 | 2.24 | 3.000 | 38.74 | 82.0 | 29.06 | 133.0 | 132.8 | 0.2 | 0.15 |
| 15 | 15.459 | 44.54 | 0.6885 | 33.0 | 0.2371 | 170.0 | 33.0 | 90.0 | 47.6 | 27.3 | 2.59 | 2.758 | 38.74 | 82.0 | 35.20 | 120.7 | 120.4 | 0.3 | 0.25 |
| 16 | 15.459 | 44.54 | 0.6885 | 33.0 | 0.2371 | 170.0 | 33.0 | 90.0 | 47.6 | 27.6 | 2.63 | 2.728 | 38.74 | 82.0 | 35.20 | 120.3 | 120.4 | −0.1 | −0.08 |
| 19 | 15.459 | 44.54 | 0.6885 | 33.0 | 0.2371 | 170.0 | 33.0 | 90.0 | 48.1 | 27.2 | 2.60 | 2.748 | 38.74 | 82.0 | 35.20 | 120.6 | 120.4 | 0.2 | 0.17 |
| 10 | 6.736 | 26.72 | 0.1800 | 33.0 | 0.1422 | 170.0 | 35.0 | 90.0 | 50.0 | 26.2 | 2.56 | 2.772 | 38.74 | 81.9 | 11.82 | 197.9 | 204.7 | −6.8 | −3.32[h] |
| 11 | 6.736 | 48.99 | 0.3300 | 25.0 | 0.1976 | 170.0 | 34.0 | 90.0 | 49.2 | 29.5 | 3.00 | 2.528 | 38.74 | 81.9 | 34.09 | 118.6 | 122.9 | −4.3 | −3.50[h] |

[a] $L_f = [(K \text{ no.})(0.292) - 2.53]Y/100)$, %.
[b] $-\ln = -\ln[(L_f - 1.00)/25.00]$.
[c] $e = e^{40-(16{,}100/Tm)Tm}$, °Abs.
[d] $t = tu\ \{1 - Tm^2/[16{,}100(Tm - T_0)]\}$, $Tm$ and $T_0$, °Abs.
[e] $c_{av.} = ci - (0.0663)(ci/cw) - 5.05$.
[f] $\Delta$ = Calc. $t_t$ − Act. $t_t$, min.
[g] % Error = $(100)\Delta$/Act. $t_t$.
[h] These significantly higher, negative errors indicate a different and slower reaction rate than in other cooks. See the discussion.

The $e^{40}$ is inserted for convenience in calculation. Thus,

$$-5.22 \times 10^{-5} = (e^{-40})\alpha_2' - \alpha_2,$$

the apparent rate constant for equation (13).

Equation (13) precisely defines the interrelationship of the cooking variables for the system studied under certain broad limitations on the values of a few of the variables. (These limitations and the absence of sulfidity or effective alkali in the rate equation are discussed in the next section.) An idea of the reproducibility possible may be obtained by comparing cooks 15, 16, and 19—all replicates of the same set of cooking conditions. The standard deviation determined on all cooks (except cooks 10 and 11—see "Discussion" below) is 30 sec. The 95% confidence limits on "Calcd. $t_t$" are about ±1.0 minute. This corresponds to a maximum error of ±0.88%. The average deviation of "calculated" from "actual" $t_t$, regardless of sign, is about 25 seconds, corresponding to a maximum error of 0.31%.

## DISCUSSION

### *Absence of Sulfidity in the Rate Expression*

It is at first startling that sulfidity or some measure of sulfide concentration is not included as such in the integrated rate expression [equation (13)]. This is because sulfidity above 33% or, more significantly, sulfide expressed in terms of molar concentration (which covers about a threefold range—see Table I) is not a determining variable in the system studied. Rather, it is *active alkali* regardless of its composition (sulfidity) which is important. (However, see the minimal sulfide requirement discussed under "Limitations Applying to the Rate Expression.")

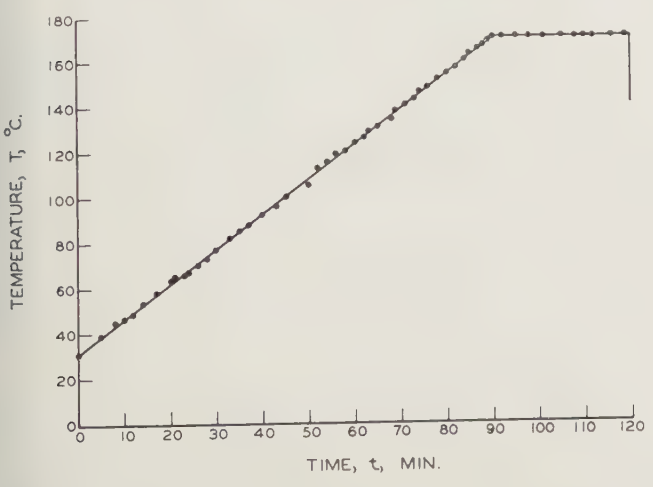


*Fig. 4. Typical temperature-time data for experimental cooks*

An expedient explanation of this situation can be devised by assuming that virtually all the $Na_2S$ hydrolyzes to NaHS and NaOH, and that nearly all of the NaHS thus formed immediately hydrolyzes further to $H_2S$ and more NaOH. The $H_2S$ resulting from this virtually complete hydrolysis of $Na_2S$ could possibly form an activated complex with the lignin and allow for easier removal by NaOH than is the case in the soda process. The *possibility* of $H_2S$ being an active cooking chemical in kraft pulping has been expressed elsewhere [see, e.g. (*19*)].

A more realistic explanation of the absence of sulfidity in the rate expression is based on the likelihood that kraft pulping reactions involve many "simultaneous" reactions having comparable rates. For the particular system studied, the complexity of the resulting situation [see, e.g. (*20*)] was probably such that active alkali was only *apparently* rate controlling. Actually, though, there probably occurs in kraft pulping a somewhat incomplete hydrolysis of $Na_2S$ ["effective alkali" concept, see, e.g. (*19*)], and the concentrations of all reactive components present during a cook are kinetically important.

### *Application of the Rate Expression*

Equation (13) is directly applicable only to the specific system described in the experimental procedure. That is, the particular "best-fit" constants appearing in equation (13) are characteristic of this system alone, provided close control is maintained during the cooks and the conditions discussed below (also characteristics of the system) are met. Certain of the constants may have more fundamental significance and be more "universal" than others; however, this is only speculation. (In this connection, see the discussion section on constants.) Thus, application of the general form of equation (13) to another *similar* system implies that

the constants must be determined by analysis of data taken under carefully controlled conditions wherein the limitations mentioned below are not violated.

#### *Limitations Applying to the Rate Expression*

For the system studied, certain limitations apply to the use of equation (13) (and thus to the mathematical model for which it was developed). The values of $c_i$, $c_w$, and sulfidity must be such that a condition of "limiting sulfide" is avoided. In cooks 10 and 11, possibly sodium sulfide (or a derivative of it) rather than NaOH (which can be considered to be rate-controlling in the other cooks) was the component reacting at the limiting rate because of its presence in insufficient amounts. This resulted in a $K$ no. higher than that which is predicted by equation (13). Such an outcome is to be expected and is consistent with recent literature concerning a limiting sulfide concept [see, e.g. (*21*)].

Apparently, a condition of limiting sulfide is avoided, *for the system studied*, by maintaining the following conditions:

$$c_i \geq 31.18 \text{ g./l.}$$

$$\text{liquor-to-wood ratio} = (c_w/c_i)1000 \geq 6.736 \text{ ml./g.}$$

$$\text{sulfidity} = \frac{(Na_2S)100}{NaOH + Na_2S} \geq 33$$

Another limitation applying to equation (13) is that the volume of liquor circulated must be sufficient to preclude "channeling." Also, the equation has not been tested outside of the 23 to 27.5 $K$ no. range (40-ml. basis) and, consequently, should be used beyond this range only with due reserve.

Still another limitation involves the temperature-time schedule. Equation (13) has been developed and thus holds for a straight-line rise up to maximum temperature, $T_m$, which is then maintained constant. Other temperature-time relationships could be incorporated by integrating (perhaps graphically, or in a tabular manner [see (10)]) the appropriate function in the derivation of the rate expression.

#### *Constants in the Rate Expression*

Equation (13) was derived and presumably gains much of its precision from incorporation of certain, more or less, fundamental concepts. It must, nevertheless be looked upon as an *empirical* rate expression. The greater utility of equation (11) than equation (7) due to the inclusion of an empirical, additional consumption factor, $\alpha_8$, and the empirical manner whereby pulp lignin is estimated from $K$ no. (see discussion below) indicate this empirical nature. In addition, for the system and limitations involved, equation (13) predicts the specific results or *outcome* of cooks characterized by pulps having a $K$ no. in a given range. The expression does not (nor was it developed to) describe accurately the *course* and accompanying characteristics of the reaction. Thus, in general, *kinetic* interpretation of equation (13) is inappropriate.

In spite of the empirical nature of equation (13), the "best-fit" values of certain of the constants may be of interest if not of theoretical significance. For instance, the residual lignin content, $\alpha_1$ [equation (13) is very sensitive to changes in $\alpha_1$], has the value, 1.00, corresponding to 1% "unavailable" or "difficultly removed" lignin. This value is consistent with Kulkarni and Nolan's work (*2*) and the observations of others (e.g., *4* and *5*). No doubt, the value of $\alpha_1$ is actually dependent upon the $K$ no. range to which the cooks are made [see, e.g. (*3*)].

The apparent rate constant, $\alpha_2$ ($= -5.22 \times 10^{-5}$), compares fairly closely with that found in the preliminary studies based on Hart and Strapp's data (*18*). Their study was of a somewhat similar system. [However, see the discussion in (*1*).] The value of $\alpha_2$ for a given rate-limiting condition is probably highly characteristic of the system. Thus, the type of wood, its moisture content, the nature of the chips, the size of the digester, final yield range, etc., all influence $\alpha_2$.

A value of 16,100 was used for $\alpha_3$ (related to the apparent heat of activation for the *gross* reaction). This value was found to be satisfactory in Vroom's work (*10*). Since equation (13) is not too sensitive to $\alpha_3$, and since $\alpha_3$ relates to the gross reaction, the particular value of 16,100 must be considered empirical.

Constants $\alpha_4$, $\alpha_5$, $\alpha_7$, and $\alpha_8$ relate to chemical consumption. For certain of Hart and Strapp's data, an $\alpha_4$ of 0.085 and $\alpha_5$ of 0.001 appeared to be "best-fit" values in the 50% yield and 25 $K$ no. range. The value of $L_i$ was 25.97 and a best-fit $\alpha_1$ seemed to be 1.00. Substituting these values into the chemical consumption portion of equation (6), it is seen that consumption, when cooking to the yield range involved, was $[0.085 + 0.001(25.97 - 1.00)]100 \cong 11\%$ based on the o.d. wood charge. This is quantitatively consistent with the 12% chemical charge often considered to be the minimum necessary in pulping for defibering satisfactorily to 50% yield in the slower soda process (*14*). The quantitative significance of constants $\alpha_7$ and $\alpha_8$ in equations (11) and (12) of the present work is unknown.

Finally, the quantitative significance of the constants (0.292 and 2.53) in equation (9) relating final pulp lignin content, $L_f$, to $K$ no., is also unknown. This is because the lignin which is reactive to pulping chemicals in the digester under the severe reaction conditions there, is probably not the same lignin which is reactive at room temperature to $KMnO_4$ in the $K$ no. determination. The initial wood lignin content, $L_i$, as measured by conventional wood lignin procedures, is also related in an unknown manner to the lignin reactive under cooking conditions. Because of this, and because the lignin content of sprucewood probably varies less than the range over which $L_i$ could vary without important consequences to the fitting of the experimental results, $L_i$ was not actually determined, but was set at a typical value: 26% [Note: Hart and Strapp's spruce (*18*) was 25.97% lignin.] Thus, $L_i$, can be looked upon as a characteristic of the system rather than literally as the initial reactive lignin content of the wood. In this connection, the important point is that through proper adjustment of constants, equation (13) accurately predicts the outcome of allowable cooks. The utility of equation (13) is its primary justification.

#### *Problems in Developing Rate Expressions*

The discussion so far may shed some light on certain problems which have possibly precluded an earlier development of a comprehensive pulping rate expression. Studying pulping reactions over too wide a range, both

with respect to the cooking variables and the degree of pulping, has perhaps been the greatest impediment. Such studies involve such a variety of reaction conditions, it is likely that a number of rate-controlling factors are involved in the removal of even a *given constituent.* Such a situation may prevail not only from cook to cook but also during a given cook. A single relatively simple rate expression (continuous in the first derivative and lacking "easement" features) cannot be expected to be useful under these conditions. In addition, due to the complexity of wood and, consequently, of the reactions in which it is involved, only a correspondingly complex set of rate expressions could predict a *gross* phenomenon such as yield as a function of time throughout the entire cook [see, e.g., (*3*)].

Other factors contributing to past difficulty in developing useful rate expressions include: failure to account for concentration changes during the cook; lack of quantitative consideration for the time-up-to-temperature period; inadequate temperature-time control; and failure to treat systems using shavings, sawdust, prehydrolysis treatments, etc., as possibly different from conventional systems using chips.

### *Yield as a Function of Average Concentration*

The effect of concentration on yield is often evaluated in pulping studies. The following can be concluded from the experimental results for the system studied (see Table I):

1. For a given average concentration, yield probably decreases insignificantly with a reduction (by means of longer cooks) in final $K$ no. in the 23 to 27.5 range. Thus, any concentration effect on yield would seem to come mainly earlier in a cook. (Compare cooks 15, 16, 19, and 20.)

2. When cooking to a given $K$ no. range (23 to 25.7) and at a given liquor-to-wood ratio, yield decreases significantly, as $c_{av.}$ increases. Thus, $Y = 49.5$ for $c_{av.} = 16.28$; $Y = 48.0$ for $c_{av.} = 43.00$ (The standard deviation for $Y$ is about 0.13%).

3. When cooking to a given $K$ no. range (23 to 25.7), increasing the liquor-to-wood ratio at a given $c_{av.}$ probably decreases yield (compare cooks 20, 21, and 22 with cooks 5, 8, and 6, respectively).

## CONCLUSIONS

1. It was possible to develop from fundamental considerations, and to experimentally verify a rather comprehensive rate expression interrelating the important kraft cooking variables in the pulping system studied. The form of the rate expression developed is expected to apply to other *similar* pulping systems provided the limitations mentioned below (2, 3, and 4) are not violated.

2. The rate expression for the system was tested for cooks in the 23 to 27.5 permanganate number range (40-ml. basis). It therefore applies with assurance only in this range.

3. The particular rate expression developed was for a straight line time-up-to-temperature schedule. Other time-temperature schedules could have been treated.

4. A significant limitation on the use of the expression *seems* to relate to the maintenance of reaction conditions characterized by sodium hydroxide as the rate-controlling constituent. Under such conditions, neither sulfidity nor molar concentration of sulfide were determining variables. Thus, they did not enter as such in the rate expression. Rather, it was active alkali which was found to be determining in the system studied.

5. The *average concentration concept* developed in this thesis is expected to be a useful concept in the development of other rate expressions and in characterizing cooking conditions.

6. Increasing the average concentration and increasing the liquor-to-wood ratio each decreased pulp yield when cooking to the same permanganate number, in the system studied.

7. The precision with which the experimental results verified virtually the same rate expression as the one theoretically developed lends credence to the validity of the assumptions and concepts in the development. However, in spite of this and the probable physical significance of several of the rate equation constants, the expression should be considered as somewhat empirical. It is definitely not a kinetic expression capable of reliably predicting orders of reaction.

8. Additional work, perhaps of a similar nature, will be necessary to quantitatively describe delignification rates over the full range of pulping conditions (especially the normal commercial range).

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# Static Pressing of Wet Sheets and Felts

ROBERT E. WHITE and FREDRIC W. BERDUX

**Pressure-temperature-moisture equilibrium data obtained by static pressing of wet sheets and felts are presented. Three types of felts and three different papers, pressed individually and in various combinations, were studied. The migration of water from felt to paper upon the release of pressure is clearly indicated.**

THE importance of the press section of the paper machine has fostered many hypotheses (*1–7*) of the mechanisms involved in the pressing operation. Because of the complexity of dynamic pressing, it does not lend itself readily to rigorous analysis or experimentation. As a result, very few quantitative data on pressing are available.

Since repeated pressing on the machine removes additional but decreasing amounts of water from the sheet, it is apparent that an equilibrium is being approached. The sheet speed, which controls the inertia of the water in the sheet and the duration of the actual pressing, limits the approach to equilibrium. It is obvious that the maximum water removed, or equilibrium, would be obtained at zero sheet speed; i.e., under static pressing conditions.

It was the purpose of this investigation to study the moisture-pressure-temperature equilibrium relationships for several papers and felts.

## MATERIALS AND APPARATUS

Three papers and three felts, individually and in various combinations, were investigated. The papers included a blotting sheet from the Standard Paper Co. and a filter paper and a disposable fabric supplied by Riegel Paper Corp.; their characteristics are given in Table I. The test samples were cut to $3^1/_2 \times 3^1/_2$ in. with a paper cutter from large sheets.

The felts were supplied by F. C. Huyck and Sons and their descriptions are given in Table II. They were conditioned prior to testing by flexing in a Di Mattia Rubber Flexometer. A flexure cycle was from full length to double bend to full length. Three 4-in. square samples of each felt were subjected 72,000 flexure cycles in both the warp and weft directions at the rate of 300 c.p.m. and were sprayed with water once an hour during the flexing. The samples were then washed in a mild detergent, dried at 100°C. for 24 hr., and dry weights determined. The felts were found to have shrunk in the warp direction and elongated in the weft direction. They were then trimmed to $3^1/_2 \times 3^1/_2$ in. and a new dry weight calculated from the weight of the trimmings. Three samples of each felt, so preconditioned, were used throughout the study.

The various samples were pressed in a Carver laboratory press equipped with electrically heated platens. The press has a $1^1/_4$-in. diam. ram and a total load of 17,000 lb. could be applied through the ram. The samples were held between two $4 \times 4 \times {}^1/_4$-in. brass plates inserted between the platens.

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## EXPERIMENTAL PROCEDURE AND DATA

The paper and felt samples were soaked in water for 24 hr. prior to pressing. For the 80°F. tests, the samples were soaked in 80°F. water; for the 120°F. and 150°F. tests, the samples were soaked at 80°F. for 20 hr. and at 120 or 150°F. for 4 hr. prior to pressing. The brass plates and the platens were heated to test temperature, the sample or combination of samples then placed between the brass plates and inserted in the press. The desired pressure was rapidly applied to the sample and held constant for 5 min. Preliminary tests showed that this was ample time to establish equilibrium. Water expressed from the sample was siphoned away with a hypodermic needle and aspirator. To minimize evaporation in the high temperature tests, this water was not removed until just prior to releasing the pressure. The thickness of the sample under pressure was also determined.

**Table I**

| *Paper →* | *Blotting* | *Filter* | *Disposable fabric* |
|---|---|---|---|
| Source | Standard | Riegel | Riegel |
| Furnish | Soda and sulfite | Cotton linter | Viscose |
| Basis weight, 500—24 × 36 | 190 | 65 | 35 |
| Sizing | None | None | None |

**Table II**

| *Felt →* | *Kraft fourdrinier* | *Yankee wet* | *Yankee pickup* |
|---|---|---|---|
| Source | Huyck | Huyck | Huyck |
| Class | Common wet | Common wet | Pickup |
| Weave | A | Plain | 4 Harness twill |
| Content | 83% wool, 17% nylon | 85% wool, 15% nylon | 100% wool |
| Weight | 2.8 oz./ft.$^2$ | 2.3 oz./ft.$^2$ | 3.5 oz./ft.$^2$ |

When the pressure was released, the samples were immediately placed in tared, covered aluminum weighing cans and weighed. The paper samples were then examined for texture and their water content and dry weight determined. Felt samples were weighed and their moisture content calculated from their known dry weights. They were then re-immersed in tap water for 24 hr. and re-used.

Temperature-pressure-moisture relationships were measured for the following arrangements at 80, 120, and 150°F.

| | |
|---|---|
| Papers | Individually, one thickness |
| Felts | Individually, one thickness |
| Paper-felt | Various combinations of one thickness of each |
| Felt-paper-felt | Various combinations of one thickness of paper between two similar felts and also two different felts |
| Felt-cellophane-paper | Combinations of one thickness of each separated by cellophane |

**Table III**

| Pressure, p.s.i.g. | Temperature, °F. | Moisture, lb./lb. Top felt | Paper | Bottom felt |
|---|---|---|---|---|
| | | Blotting Paper | | |
| 150 | 80 | | 1.01 | |
| | 120 | | 0.85 | |
| | 150 | | 0.72 | |
| 300 | 80 | | 0.80 | |
| | 120 | | 0.70 | |
| | 150 | | 0.59 | |
| 500 | 80 | | 0.68 | |
| | 120 | | 0.61 | |
| | 150 | | 0.51 | |
| 700 | 80 | | 0.60 | |
| | 120 | | 0.54 | |
| | 150 | | 0.46 | |
| 900 | 80 | | 0.55 | |
| | 120 | | 0.50 | |
| | 150 | | 0.44 | |
| 1100 | 80 | | 0.52 | |
| | 120 | | 0.47 | |
| | 150 | | 0.41 | |
| 1300 | 80 | | 0.50 | |
| | 120 | | 0.45 | |
| | 150 | | 0.40 | |
| | | Riegel Filter Paper | | |
| 150 | 80 | | 1.29 | |
| | 120 | | 1.17 | |
| 300 | 80 | | 1.04 | |
| | 120 | | 0.94 | |
| 500 | 80 | | 0.89 | |
| | 120 | | 0.80 | |
| 700 | 80 | | 0.76 | |
| | 120 | | 0.69 | |
| 900 | 80 | | 0.68 | |
| | 120 | | 0.63 | |
| 1100 | 80 | | 0.59 | |
| | 120 | | 0.57 | |
| 1300 | 80 | | 0.53 | |
| | 120 | | 0.40 | |
| | | Riegel Disposable Fabric | | |
| 150 | 80 | | 1.51 | |
| | 120 | | 1.20 | |
| 300 | 80 | | 1.12 | |
| | 120 | | 0.88 | |
| 500 | 80 | | 0.84 | |
| | 120 | | 0.71 | |
| 700 | 80 | | 0.78 | |
| | 120 | | 0.59 | |
| 900 | 80 | | 0.69 | |
| | 120 | | 0.53 | |
| 1100 | 80 | | 0.64 | |
| | 120 | | 0.51 | |
| | | Yankee Wet Felt | | |
| 150 | 80 | 1.01 | | |
| | 120 | 0.94 | | |
| | 150 | 0.82 | | |
| 300 | 80 | 0.82 | | |
| | 120 | 0.74 | | |
| | 150 | 0.66 | | |
| 500 | 80 | 0.69 | | |
| | 120 | 0.62 | | |
| | 150 | 0.57 | | |
| 700 | 80 | 0.64 | | |
| | 120 | 0.57 | | |
| | 150 | 0.50 | | |
| 900 | 80 | 0.60 | | |
| | 120 | 0.52 | | |
| | 150 | 0.47 | | |
| 1100 | 80 | 0.58 | | |
| | 120 | 0.52 | | |
| | 150 | 0.45 | | |
| 1300 | 80 | 0.57 | | |
| | 120 | 0.51 | | |
| | 150 | 0.44 | | |
| | | Kraft Fourdrinier Felt | | |
| 150 | 80 | 1.09 | | |
| | 120 | 1.00 | | |
| | 150 | 0.93 | | |
| 300 | 80 | 0.87 | | |
| | 120 | 0.80 | | |
| | 150 | 0.73 | | |
| 500 | 80 | 0.74 | | |
| | 120 | 0.65 | | |
| | 150 | 0.60 | | |
| 700 | 80 | 0.57 | | |
| | 120 | 0.60 | | |
| | 150 | 0.54 | | |
| 900 | 80 | 0.64 | | |
| | 120 | 0.56 | | |
| | 150 | 0.49 | | |
| 1100 | 80 | 0.62 | | |
| | 120 | 0.52 | | |
| | 150 | 0.47 | | |
| 1300 | 80 | 0.59 | | |
| | 120 | 0.50 | | |
| | 150 | 0.44 | | |
| | | Yankee Pickup Felt | | |
| 150 | 80 | 0.86 | | |
| | 120 | 0.81 | | |
| | 150 | 0.75 | | |
| 300 | 80 | 0.67 | | |
| | 120 | 0.61 | | |
| | 150 | 0.55 | | |
| 500 | 80 | 0.56 | | |
| | 120 | 0.52 | | |
| | 150 | 0.46 | | |
| 700 | 80 | 0.52 | | |
| | 120 | 0.45 | | |
| | 150 | 0.42 | | |
| 900 | 80 | 0.50 | | |
| | 120 | 0.43 | | |
| | 150 | 0.38 | | |
| 1100 | 80 | 0.48 | | |
| | 120 | 0.41 | | |
| | 150 | 0.36 | | |
| 1300 | 80 | 0.47 | | |
| | 120 | 0.39 | | |
| | 150 | 0.34 | | |
| | | Blotting Paper and Yankee Wet Felt | | |
| 150 | 80 | 0.82 | 1.28 | |
| | 120 | 0.69 | 1.12 | |
| | 150 | 0.62 | 0.87 | |
| 300 | 80 | 0.66 | 1.00 | |
| | 120 | 0.58 | 0.82 | |
| | 150 | 0.50 | 0.71 | |
| 500 | 80 | 0.57 | 0.74 | |
| | 120 | 0.50 | 0.68 | |
| | 150 | 0.42 | 0.60 | |
| 700 | 80 | 0.53 | 0.69 | |
| | 120 | 0.44 | 0.60 | |
| | 150 | 0.37 | 0.52 | |
| 900 | 80 | 0.49 | 0.61 | |
| | 120 | 0.40 | 0.55 | |
| | 150 | 0.34 | 0.48 | |
| 1100 | 80 | 0.43 | 0.57 | |
| | 120 | 0.37 | 0.51 | |
| | 150 | 0.31 | 0.45 | |
| 1300 | 80 | 0.38 | 0.55 | |
| | 120 | 0.35 | 0.49 | |
| | 150 | 0.33 | 0.43 | |
| | | Blotting Paper and Kraft Fourdrinier Felt | | |
| 150 | 80 | 0.89 | 1.30 | |
| | 120 | 0.77 | 1.15 | |
| | 150 | 0.70 | 0.97 | |
| 300 | 80 | 0.74 | 1.07 | |
| | 120 | 0.65 | 0.92 | |
| | 150 | 0.57 | 0.77 | |
| 500 | 80 | 0.61 | 0.78 | |
| | 120 | 0.54 | 0.71 | |
| | 150 | 0.48 | 0.62 | |
| 700 | 80 | 0.58 | 0.69 | |
| | 120 | 0.48 | 0.62 | |
| | 150 | 0.41 | 0.52 | |
| 900 | 80 | 0.51 | 0.67 | |
| | 120 | 0.45 | 0.56 | |
| | 150 | 0.37 | 0.49 | |
| 1100 | 80 | 0.47 | 0.60 | |
| | 120 | 0.41 | 0.52 | |
| | 150 | 0.35 | 0.45 | |
| 1300 | 80 | 0.46 | 0.55 | |
| | 120 | 0.39 | 0.50 | |
| | 150 | 0.34 | 0.43 | |

| Pressure, p.s.i.g. | Temperature, °F. | Moisture, lb./lb. Top felt | Paper | Bottom felt |
|---|---|---|---|---|
| | **Blotting Paper and Yankee Pickup Felt** | | | |
| 150 | 80 | 0.79 | 1.38 | |
| | 120 | 0.72 | 1.1 | |
| | 150 | 0.64 | 0.86 | |
| 300 | 80 | 0.66 | 1.01 | |
| | 120 | 0.58 | 0.82 | |
| | 150 | 0.51 | 0.66 | |
| 500 | 80 | 0.57 | 0.78 | |
| | 120 | 0.49 | 0.66 | |
| | 150 | 0.42 | 0.57 | |
| 700 | 80 | 0.56 | 0.72 | |
| | 120 | 0.43 | 0.55 | |
| | 150 | 0.37 | 0.47 | |
| 900 | 80 | 0.47 | 0.57 | |
| | 120 | 0.40 | 0.51 | |
| | 150 | 0.36 | 0.45 | |
| 1100 | 80 | 0.46 | 0.54 | |
| | 120 | 0.38 | 0.48 | |
| | 150 | 0.33 | 0.39 | |
| 1300 | 80 | 0.43 | 0.53 | |
| | 120 | 0.36 | 0.46 | |
| | 150 | 0.31 | 0.37 | |
| | **Filter Paper and Yankee Wet Felt** | | | |
| 150 | 80 | 0.86 | 2.26 | |
| | 120 | 0.73 | 1.93 | |
| 300 | 80 | 0.68 | 1.76 | |
| | 120 | 0.56 | 1.40 | |
| 500 | 80 | 0.58 | 1.31 | |
| | 120 | 0.48 | 1.04 | |
| 700 | 80 | 0.50 | 1.11 | |
| | 120 | 0.41 | 0.90 | |
| 900 | 80 | 0.47 | 0.98 | |
| | 120 | 0.38 | 0.79 | |
| 1100 | 80 | 0.44 | 0.94 | |
| | 120 | 0.36 | 0.73 | |
| 1300 | 80 | 0.42 | 0.87 | |
| | 120 | 0.35 | 0.70 | |
| | **Filter Paper and Kraft Fourdrinier Felt** | | | |
| 150 | 80 | 0.88 | 2.25 | |
| | 120 | 0.73 | 1.98 | |
| 300 | 80 | 0.72 | 1.76 | |
| | 120 | 0.59 | 1.44 | |
| 500 | 80 | 0.59 | 1.38 | |
| | 120 | 0.48 | 1.14 | |
| 700 | 80 | 0.52 | 1.14 | |
| | 120 | 0.42 | 0.94 | |
| 900 | 80 | 0.52 | 1.03 | |
| | 120 | 0.41 | 0.82 | |
| 1100 | 80 | 0.50 | 0.93 | |
| | 120 | 0.38 | 0.75 | |
| 1300 | 80 | 0.46 | 0.90 | |
| | 120 | 0.36 | 0.65 | |
| | **Filter Paper and Yankee Pickup Felt** | | | |
| 150 | 80 | 0.85 | 1.98 | |
| | 120 | 0.75 | 1.70 | |
| 300 | 80 | 0.71 | 1.43 | |
| | 120 | 0.59 | 1.24 | |
| 500 | 80 | 0.59 | 1.12 | |
| | 120 | 0.51 | 0.82 | |
| 700 | 80 | 0.54 | 0.97 | |
| | 120 | 0.43 | 0.81 | |
| 900 | 80 | 0.50 | 0.82 | |
| | 120 | 0.39 | 0.71 | |
| 1100 | 80 | 0.46 | 0.76 | |
| | 120 | 0.37 | 0.63 | |
| 1300 | 80 | 0.44 | 0.77 | |
| | 120 | 0.36 | 0.54 | |
| | **Disposable Fabric and Yankee Wet Felt** | | | |
| 150 | 80 | 0.87 | 2.43 | |
| | 120 | 0.75 | 1.83 | |
| 300 | 80 | 0.71 | 1.80 | |
| | 120 | 0.57 | 1.17 | |
| 500 | 80 | 0.60 | 1.41 | |
| | 120 | 0.48 | 0.87 | |
| 700 | 80 | 0.52 | 1.12 | |
| | 120 | 0.45 | 0.81 | |
| 900 | 80 | 0.49 | 1.02 | |
| | 120 | 0.41 | 0.77 | |
| 1100 | 80 | 0.46 | 0.98 | |
| | 120 | 0.40 | 0.72 | |
| 1300 | 80 | 0.43 | 0.96 | |
| | 120 | 0.39 | 0.74 | |
| | **Disposable Fabric and Kraft Fourdrinier Felt** | | | |
| 150 | 80 | 0.95 | 2.67 | |
| | 120 | 0.83 | 1.99 | |
| 300 | 80 | 0.77 | 1.90 | |
| | 120 | 0.63 | 1.37 | |
| 500 | 80 | 0.64 | 1.37 | |
| | 120 | 0.52 | 0.98 | |
| 700 | 80 | 0.54 | 1.04 | |
| | 120 | 0.46 | 0.85 | |
| 900 | 80 | 0.51 | 1.03 | |
| | 120 | 0.42 | 0.77 | |
| 1100 | 80 | 0.50 | 0.99 | |
| | 120 | 0.42 | 0.76 | |
| 1300 | 80 | 0.47 | 0.98 | |
| | 120 | 0.40 | 0.74 | |
| | **Disposable Fabric and Yankee Pickup Felt** | | | |
| 150 | 80 | 0.92 | 2.22 | |
| | 120 | 0.80 | 1.66 | |
| 300 | 80 | 0.75 | 1.65 | |
| | 120 | 0.62 | 1.19 | |
| 500 | 80 | 0.60 | 1.22 | |
| | 120 | 0.52 | 0.93 | |
| 700 | 80 | 0.58 | 1.13 | |
| | 120 | 0.46 | 0.82 | |
| 900 | 80 | 0.46 | 1.03 | |
| | 120 | 0.41 | 0.81 | |
| 1100 | 80 | 0.42 | 0.95 | |
| | 120 | 0.38 | 0.76 | |
| 1300 | 80 | 0.41 | 0.94 | |
| | 120 | 0.36 | 0.74 | |
| | **Blotting Paper and Yankee Wet Felts** | | | |
| 150 | 80 | 0.77 | 1.44 | 0.78 |
| | 120 | 0.71 | 1.24 | 0.72 |
| | 150 | 0.68 | 1.00 | 0.67 |
| 300 | 80 | 0.61 | 1.37 | 0.62 |
| | 120 | 0.57 | 1.01 | 0.57 |
| | 150 | 0.53 | 0.89 | 0.54 |
| 500 | 80 | 0.52 | 0.99 | 0.52 |
| | 120 | 0.47 | 0.81 | 0.47 |
| | 150 | 0.42 | 0.68 | 0.40 |
| 700 | 80 | 0.46 | 0.81 | 0.46 |
| | 120 | 0.43 | 0.70 | 0.42 |
| | 150 | 0.38 | 0.59 | 0.37 |
| 900 | 80 | 0.45 | 0.72 | 0.48 |
| | 120 | 0.38 | 0.63 | 0.38 |
| | 150 | 0.35 | 0.56 | 0.35 |
| 1100 | 80 | 0.44 | 0.70 | 0.44 |
| | 120 | 0.36 | 0.59 | 0.36 |
| | 150 | 0.34 | 0.53 | 0.33 |
| 1300 | 80 | 0.40 | 0.64 | 0.40 |
| | 120 | 0.36 | 0.57 | 0.36 |
| | 150 | 0.30 | 0.50 | 0.30 |
| | **Blotting Paper and Kraft Fourdrinier Felts** | | | |
| 150 | 80 | 0.87 | 1.47 | 0.88 |
| | 120 | 0.78 | 1.30 | 0.78 |
| | 150 | 0.74 | 1.13 | 0.71 |
| 300 | 80 | 0.68 | 1.20 | 0.69 |
| | 120 | 0.62 | 1.02 | 0.62 |
| | 150 | 0.55 | 0.82 | 0.56 |
| 500 | 80 | 0.61 | 1.05 | 0.61 |
| | 120 | 0.51 | 0.79 | 0.51 |
| | 150 | 0.45 | 0.67 | 0.45 |
| 700 | 80 | 0.52 | 0.85 | 0.53 |
| | 120 | 0.45 | 0.67 | 0.45 |
| | 150 | 0.41 | 0.59 | 0.40 |
| 900 | 80 | 0.49 | 0.72 | 0.49 |
| | 120 | 0.41 | 0.60 | 0.42 |
| | 150 | 0.36 | 0.51 | 0.36 |
| 1100 | 80 | 0.47 | 0.70 | 0.47 |
| | 120 | 0.39 | 0.58 | 0.39 |
| | 150 | 0.35 | 0.52 | 0.35 |
| 1300 | 80 | 0.43 | 0.64 | 0.43 |
| | 120 | 0.36 | 0.56 | 0.36 |
| | 150 | 0.32 | 0.48 | 0.32 |
| | **Blotting Paper and Yankee Pickup Felts** | | | |
| 150 | 80 | 0.77 | 1.51 | 0.77 |
| | 120 | 0.69 | 1.29 | 0.70 |
| | 150 | 0.64 | 1.11 | 0.64 |

| Pressure, p.s.i.g. | Temperature, °F. | Moisture, lb./lb. Top felt | Paper | Bottom felt |
|---|---|---|---|---|
| 300 | 80 | 0.61 | 1.28 | 0.62 |
| | 120 | 0.58 | 1.03 | 0.57 |
| | 150 | 0.51 | 0.82 | 0.51 |
| 500 | 80 | 0.54 | 1.03 | 0.53 |
| | 120 | 0.46 | 0.84 | 0.47 |
| | 150 | 0.43 | 0.68 | 0.44 |
| 700 | 80 | 0.48 | 0.83 | 0.48 |
| | 120 | 0.42 | 0.68 | 0.41 |
| | 150 | 0.39 | 0.58 | 0.40 |
| 900 | 80 | 0.46 | 0.73 | 0.46 |
| | 120 | 0.39 | 0.59 | 0.39 |
| | 150 | 0.33 | 0.49 | 0.33 |
| 1100 | 80 | 0.44 | 0.65 | 0.44 |
| | 120 | 0.35 | 0.54 | 0.34 |
| | 150 | 0.32 | 0.52 | 0.32 |
| 1300 | 80 | 0.42 | 0.63 | 0.42 |
| | 120 | 0.35 | 0.52 | 0.35 |
| | 150 | 0.30 | 0.45 | 0.30 |
| | Filter Paper and Yankee Wet Felts | | | |
| 150 | 80 | 0.88 | 2.38 | 0.87 |
| | 120 | 0.73 | 2.03 | 0.72 |
| 300 | 80 | 0.72 | 1.90 | 0.70 |
| | 120 | 0.57 | 1.54 | 0.57 |
| 500 | 80 | 0.57 | 1.44 | 0.57 |
| | 120 | 0.47 | 1.12 | 0.46 |
| 700 | 80 | 0.50 | 1.19 | 0.50 |
| | 120 | 0.41 | 0.91 | 0.41 |
| 900 | 80 | 0.47 | 1.05 | 0.47 |
| | 120 | 0.38 | 0.83 | 0.37 |
| 1100 | 80 | 0.43 | 0.93 | 0.43 |
| | 120 | 0.36 | 0.72 | 0.37 |
| 1300 | 80 | 0.42 | 0.86 | 0.42 |
| | 120 | 0.35 | 0.68 | 0.35 |
| | Filter Paper and Kraft Fourdrinier Felts | | | |
| 150 | 80 | 0.86 | 2.62 | 0.86 |
| | 120 | 0.73 | 2.20 | 0.72 |
| 300 | 80 | 0.71 | 1.94 | 0.71 |
| | 120 | 0.56 | 1.60 | 0.58 |
| 500 | 80 | 0.60 | 1.45 | 0.60 |
| | 120 | 0.47 | 1.27 | 0.47 |
| 700 | 80 | 0.55 | 1.29 | 0.55 |
| | 120 | 0.44 | 1.14 | 0.43 |
| 900 | 80 | 0.51 | 1.11 | 0.51 |
| | 120 | 0.40 | 0.94 | 0.40 |
| 1100 | 80 | 0.49 | 1.00 | 0.49 |
| | 120 | 0.39 | 0.84 | 0.38 |
| 1300 | 80 | 0.46 | 0.88 | 0.46 |
| | 120 | 0.35 | 0.72 | 0.34 |
| | Filter Paper and Yankee Pickup Felts | | | |
| 150 | 80 | 0.85 | 2.12 | 0.87 |
| | 120 | 0.77 | 1.87 | 0.77 |
| 300 | 80 | 0.71 | 1.57 | 0.70 |
| | 120 | 0.61 | 1.32 | 0.61 |
| 500 | 80 | 0.59 | 1.39 | 0.60 |
| | 120 | 0.50 | 1.01 | 0.50 |
| 700 | 80 | 0.54 | 1.00 | 0.53 |
| | 120 | 0.43 | 0.84 | 0.43 |
| 900 | 80 | 0.49 | 0.87 | 0.50 |
| | 120 | 0.40 | 0.72 | 0.40 |
| 1100 | 80 | 0.47 | 0.78 | 0.46 |
| | 120 | 0.37 | 0.64 | 0.37 |
| 1300 | 80 | 0.44 | 0.61 | 0.44 |
| | 120 | 0.35 | 0.56 | 0.35 |
| | Disposable Fabric and Yankee Wet Felts | | | |
| 150 | 80 | 0.93 | 3.04 | 0.93 |
| | 120 | 0.77 | 2.08 | 0.78 |
| 300 | 80 | 0.74 | 2.05 | 0.73 |
| | 120 | 0.61 | 1.48 | 0.60 |
| 500 | 80 | 0.61 | 1.47 | 0.61 |
| | 120 | 0.50 | 1.15 | 0.50 |
| 700 | 80 | 0.54 | 1.25 | 0.54 |
| | 120 | 0.44 | 0.99 | 0.44 |
| 900 | 80 | 0.50 | 1.13 | 0.50 |
| | 120 | 0.40 | 0.84 | 0.40 |
| 1100 | 80 | 0.47 | 1.05 | 0.47 |
| | 120 | 0.38 | 0.78 | 0.38 |
| 1300 | 80 | 0.45 | 1.02 | 0.45 |
| | 120 | 0.36 | 0.65 | 0.36 |
| | Disposable Fabric and Kraft Fourdrinier Felts | | | |
| 150 | 80 | 1.04 | 3.41 | 1.04 |
| | 120 | 0.88 | 2.33 | 0.88 |
| 300 | 80 | 0.79 | 2.14 | 0.78 |
| | 120 | 0.66 | 1.58 | 0.66 |
| 500 | 80 | 0.64 | 1.51 | 0.64 |
| | 120 | 0.54 | 1.19 | 0.54 |
| 700 | 80 | 0.56 | 1.28 | 0.56 |
| | 120 | 0.47 | 1.03 | 0.47 |
| 900 | 80 | 0.52 | 1.20 | 0.51 |
| | 120 | 0.43 | 1.01 | 0.43 |
| 1100 | 80 | 0.49 | 1.17 | 0.49 |
| | 120 | 0.40 | 0.97 | 0.40 |
| 1300 | 80 | 0.48 | 1.15 | 0.48 |
| | 120 | 0.39 | 0.95 | 0.39 |
| | Disposable Fabric and Yankee Pickup Felts | | | |
| 150 | 80 | 0.98 | 2.32 | 0.98 |
| | 120 | 0.83 | 1.71 | 0.83 |
| 300 | 80 | 0.79 | 1.73 | 0.79 |
| | 120 | 0.66 | 1.27 | 0.66 |
| 500 | 80 | 0.63 | 1.29 | 0.63 |
| | 120 | 0.55 | 0.93 | 0.54 |
| 700 | 80 | 0.54 | 1.11 | 0.54 |
| | 120 | 0.47 | 0.84 | 0.47 |
| 900 | 80 | 0.48 | 1.02 | 0.48 |
| | 120 | 0.42 | 0.79 | 0.42 |
| 1100 | 80 | 0.44 | 0.97 | 0.44 |
| | 120 | 0.40 | 0.76 | 0.39 |
| 1300 | 80 | 0.41 | 0.97 | 0.40 |
| | 120 | 0.38 | 0.74 | 0.38 |
| | Blotting Paper, Yankee Wet Top Felt, Yankee Pickup Bottom Felt | | | |
| 150 | 150 | 0.63 | 1.12 | 0.69 |
| 300 | 150 | 0.50 | 0.91 | 0.51 |
| 500 | 150 | 0.43 | 0.75 | 0.46 |
| 700 | 150 | 0.37 | 0.60 | 0.37 |
| 900 | 150 | 0.33 | 0.53 | 0.32 |
| 1100 | 150 | 0.32 | 0.50 | 0.31 |
| 1300 | 150 | 0.29 | 0.46 | 0.30 |
| | Blotting Paper, Cellophane, Yankee Wet Felt | | | |
| 150 | 80 | 0.98 | 1.09 | |
| 500 | 80 | 0.64 | 0.70 | |
| 900 | 80 | 0.57 | 0.58 | |
| | Blotting Paper, Cellophane, Kraft Fourdrinier Felt | | | |
| 150 | 80 | 1.18 | 1.1 | |
| 500 | 80 | 0.74 | 0.69 | |
| 900 | 80 | 0.69 | 0.62 | |
| | Blotting Paper, Cellophane, Yankee Pickup Felt | | | |
| 150 | 80 | 0.86 | 1.00 | |
| 500 | 80 | 0.58 | 0.71 | |
| 900 | 80 | 0.51 | 0.57 | |

All tests were run in triplicate. The three replicates for each test were averaged and these averages are given in Table III. The standard deviation of a single determination is 0.028 lb. water per lb. dry material and the standard error of an estimate based on three replicates is 0.0156 lb. per lb. The 95% confidence limits are $\bar{x} \pm 0.031$, where $\bar{x}$ is the observed average. Some of these data are presented in Figs. 1 through 10 to illustrate the trends.

## DISCUSSION

In every case the effect of pressure on moisture content is as expected for a compressible porous material. As the pressure is increased, the change in moisture content decreases rapidly and asymptotically approaches zero. The effect of pressure is most marked in the low pressure range and diminishes rapidly as higher pressures are exerted. The more porous the material, the greater is the pressure effect at low pressures. For example, a change in pressure from 0 to 150 p.s.i.g. reduces the moisture content by 50% in the blotting paper, by 82% in the filter paper, and by 90% in the

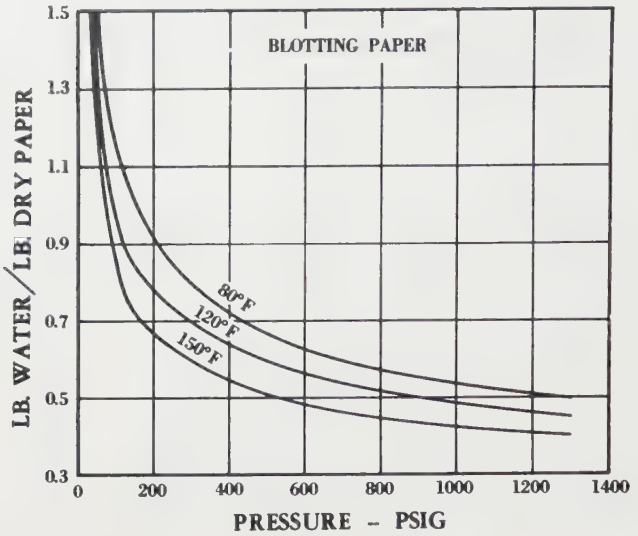


*Fig. 1. Equilibrium relationships for statically pressed blotting sheets*

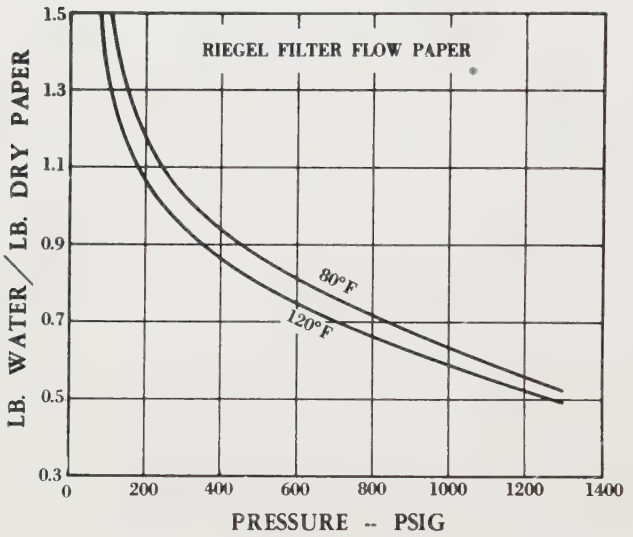


*Fig. 2. Equilibrium relationships for statically pressed filter paper*

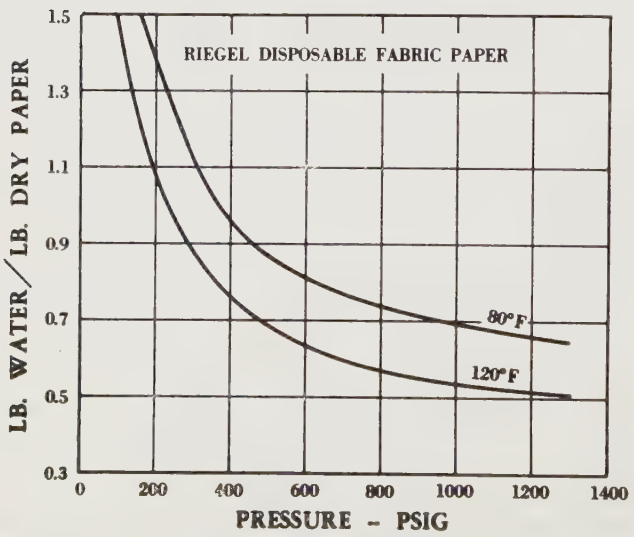


*Fig. 3. Equilibrium relationships for statically pressed disposable fabric paper*

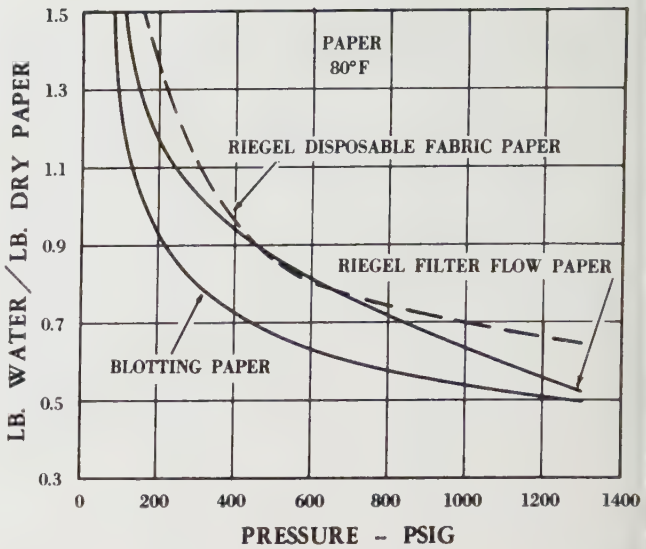


*Fig. 4. Comparative moisture values for three statically pressed papers*

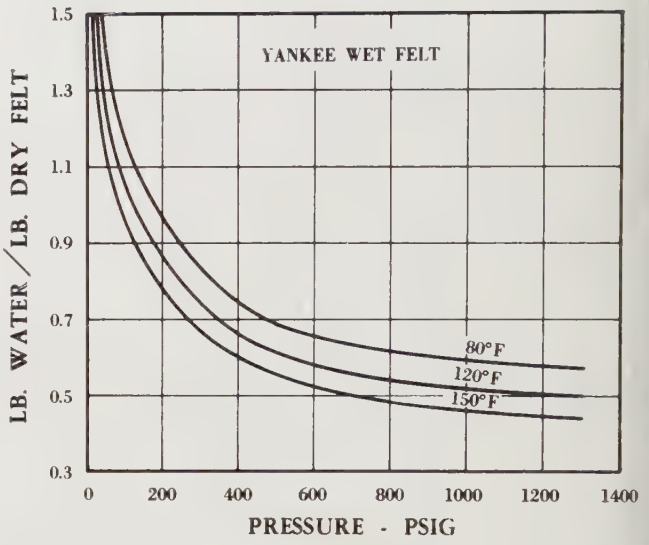


*Fig. 5. Equilibrium relationships for statically pressed yankee wet felt*

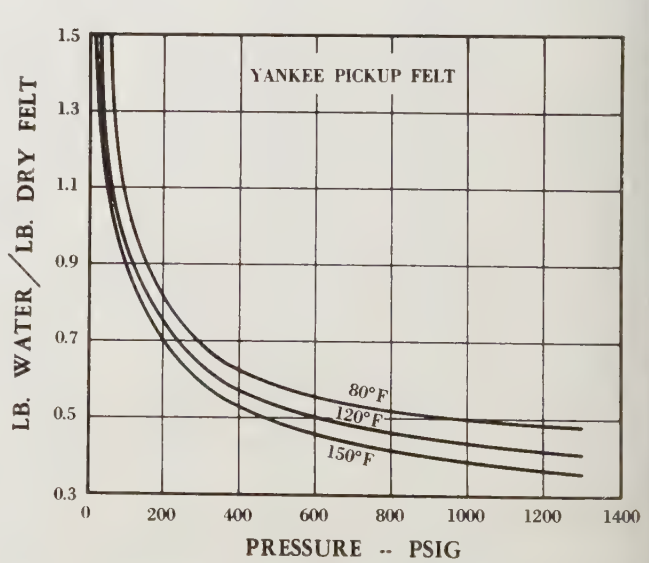


*Fig. 6. Equilibrium relationships for statically pressed yankee pickup felt*

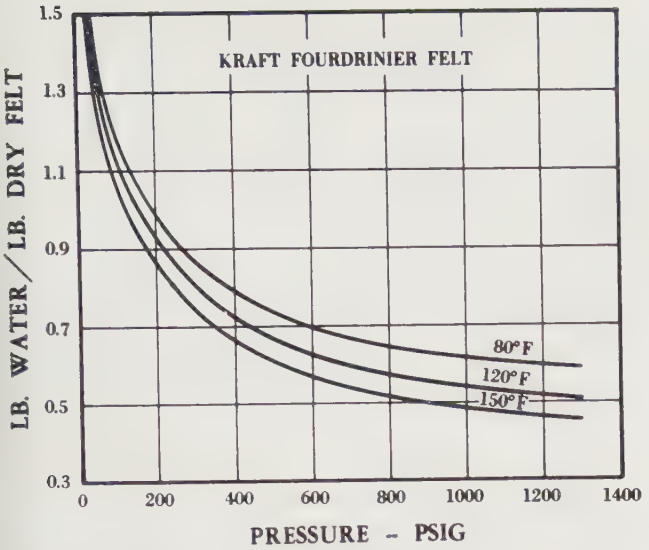


*Fig. 7. Equilibrium relationships for statically pressed kraft fourdrinier felt*

disposable fabric. Although the specific moisture content at a particular pressure differs with type of paper or felt, above 150 p.s.i.g. the fractional change in moisture for a specific change in pressure is fairly constant for all materials.

Pressing at higher temperatures always results in a drier sheet or felt. This effect has been observed on machines and is usually attributed to the decrease in viscosity of the water. This is a logical conclusion in view of the dynamic conditions involved but in these static tests viscosity loses its significance. Other causes must be considered; decreased compressive strength of the test specimens and decreased density and surface tension of the water appear most logical. Within the accuracy of the thickness measurements made during the tests, the temperature did not appear to effect the compressed thickness and, therefore, the compressive strength. The change in density, alone, is not sufficient to account for the temperature effect observed. However, if both surface tension and density are considered, a fair estimate of the effect of temperature can be made. As an example, the ratio of the surface tension-density product at 120°F. to that at 80°F. is 0.941; the ratio of

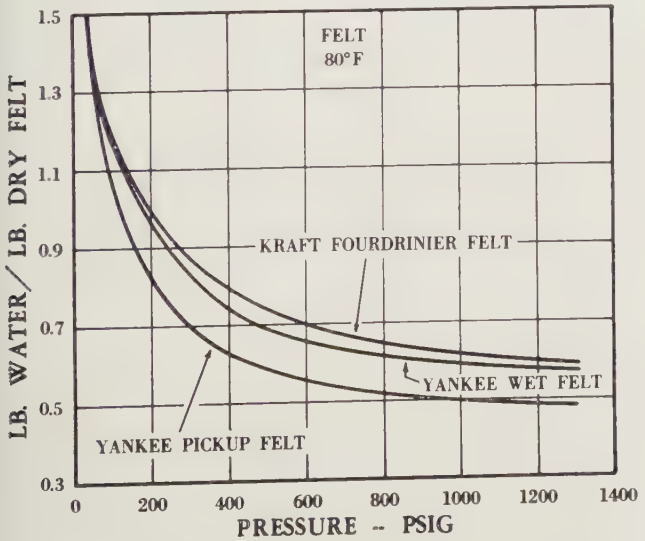


*Fig. 8. Comparative moisture values for three statically pressed felts*

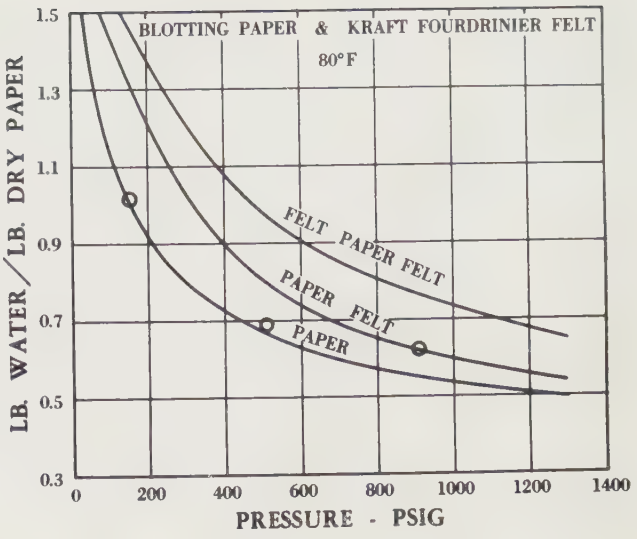


*Fig. 9. Comparative moisture values of blotting paper statically pressed alone and in combination with one and two kraft fourdrinier felts*

The individual points represent moisture values of the paper when separated from the felt by cellophane.

moisture contents at 120 and 80°F. varies from 0.80 to 0.95 for the various materials tested.

When a paper sheet is pressed in combination with a felt or felts, the moisture-pressure-temperature relationships are similar to those obtained when the individual components are pressed. However, one significant difference persists; namely, the paper is always wetter and the felt is always drier than when pressed separately under the same conditions. When two felts are used, the paper is always wetter than when only one felt is used. This is illustrated in Figs. 9 and 10. Moisture balances indicate that the total water remaining in the felt-paper combinations closely approaches the total of the water in the individually pressed components. This would suggest that the expression of the water is not far different in the case of combinations but that on the release of presssure a migration of water from the felt to the paper occurs. To substantiate this, several combinations of felt and paper were prepared with cello-

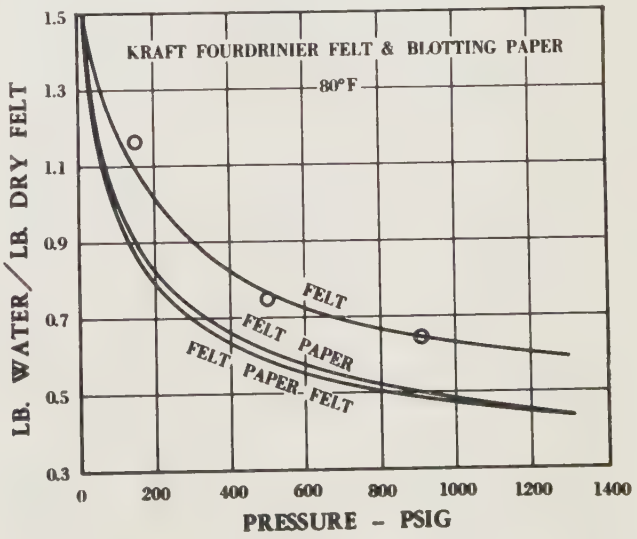


*Fig. 10. Comparative moisture values of kraft fourdrinier felt pressed alone and in combination with blotting paper*

The individual points represent moisture values of the felt when separated from the paper by cellophane.

phane sheets separating the component members. These were then pressed in the usual manner and the residual moisture contents determined. The results are shown in Figs. 9 and 10. Migration of water between felt and paper could not take place in these tests and the residual moisture in each component approaches that remaining when each is pressed alone.

This phenomenon of water migrating from felt to sheet is the result of capillary forces and, therefore, a function of the structures of felt and sheet. A study of the data indicates that, in general, the migration is strongest in the case of the disposable fabric and least in the case of blotting paper. The Kraft Fourdrinier felt allows the most water to pass to the sheet and the Yankee Pickup felt, the least. The pressure applied to the felt-sheet combination prior to release of pressure and migration of water will affect the above generalizations since all the felts do not have the same compressive strength.

### SUMMARY

Before summarizing the results of this study, it should be emphasized that there is no basis for extending static pressing data to machine performance where dynamic and highly transient conditions exist.

The effect of pressure in static pressing on the final dryness of the sheet or felt is most marked in the pressure range up to 150 p.s.i. The more porous the sheet, the greater the change in moisture with pressure. At higher pressures the effect of pressure is more independent of the material being pressed. All of the data for the pressure range of 100 to 1000 p.s.i. can be fitted to a single general equation.

Increasing temperatures aid in the release of the capillary-held water and yield drier sheets and felts.

In the cases studied, when combinations of paper and felt are pressed, the paper is always wetter and the felt is always drier than when pressed individually.

When combinations are pressed, there is a definite migration of water from felt to paper when the pressure is released. The extent of the migration depends upon the structure of the components.

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# Effect of Sulfite to Carbonate Ratio on Neutral Sulfite Semichemical Pulping

C. B. CHRISTIANSEN

**In the kraft process, sodium carbonate is recognized as an inert chemical and it has been generally assigned the same role in neutral sulfite pulping. In the latter process, it is referred to as a buffer or neutralizer of wood acids. Since a wide variety of sulfite/carbonate ratios is used commercially, the pulping effect of sodium carbonate needs study. A series of small scale cooks was made to determine the effect of sulfite/carbonate ratios on pulp yield. These were followed by similar cooks on the 2-cu. ft. scale. One sequence of time-series digestions maintained a constant charge of sodium oxide with different sulfite/carbonate ratios. In a second series of cooks, the charge of sodium sulfite remained constant while the ratio of sulfite/carbonate was varied by additions of sodium carbonate. In order to simulate conditions encountered in high yield continuous pulping, a third series of cooks of 20 min. duration were made. Maintaining the total charge of sodium oxide constant, the amounts of sulfite and carbonate were varied by 10% intervals from 0 to 100%. In the neutral sulfite process, the carbonate component was found to have an appreciable pulping effect. This was true whether it served as additional chemical or as partial replacement for the sulfite. In batch-type cooking, additions of sodium carbonate shortened cooking times without appreciably affecting strength properties. With high-yield pulps from rapid-cycle cooks the highest strength values were reached with sulfite/carbonate ratios in the range of 2 to 3. Even at sulfite/carbonate ratios near 1, strength values were not greatly reduced.**

C. B. Christiansen, Technical Service, Diamond Alkali Co., Painesville, Ohio. A contribution from the Pulp and Paper Laboratory of the Diamond Alkali Co.

Neutral sulfite pulping has been described as a method employing sodium sulfite as the active pulping agent with sodium carbonate as a buffering material to neutralize wood acids which are released during the pulping reaction. By maintaining the pH of the cook in the alkaline range, severe corrosion conditions are avoided.

The cooking liquors are generally prepared by sulfiting sodium carbonate solutions to a point which results in a final pH, after cooking, of 8.0 or more. In some mills, a final pH lower than 8.0 is considered satisfactory. Sulfite/carbonate ratios in commercial use have ranged from 10 to as low as 1.

Kesler (*1*), in a fundamental study of corrosion made for the TAPPI Corrosion Committee, demonstrated that corrosion becomes appreciable at pH 9.5 and increases in intensity as the pH decreases. From the standpoint of corrosiveness, the highest permissible use of sodium carbonate was recommended.

Bray and Eastwood (*2*) treated 25-g. samples of finely ground black gum wood with sodium sulfite and sodium bicarbonate in different ratios, while main-

**Table I. Neutral Sulfite Pulping of Mixed Hardwoods at Constant Total Sodium Charge**

Miniature Digesters

| Cooking liquor: Total $Na_2O$, % as $Na_2CO_3$ | Cooking liquor: Total $Na_2O$, % as $Na_2SO_3$ | Weight ratio of sulfite/carbonate | Pulp yields and pH of blow liquor: Cooking, 1/2 hr. Yield, % | Cooking, 1/2 hr. Final pH | Cooking, 1 hr. Yield, % | Cooking, 1 hr. Final pH | Cooking, 1 1/2 hr. Yield, % | Cooking, 1 1/2 hr. Final pH | Cooking, 2 hr. Yield, % | Cooking, 2 hr. Final pH |
|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 0 | 0 | 81.5 | ... | 79.1 | ... | 79.5 | ... | 78.0 | ... |
| 100 | 0 | 0 | 80.5 | 8.8 | 79.3 | 8.9 | 77.7 | 8.7 | 77.8 | 9.0 |
| 80 | 20 | 0.30 | 76.9 | ... | 77.1 | ... | 75.6 | ... | 76.0 | ... |
| 80 | 20 | 0.30 | 78.5 | 8.7 | 75.4 | 8.5 | 75.3 | 8.5 | 73.9 | 8.6 |
| 60 | 40 | 0.78 | 77.7 | 8.8 | 74.3 | 8.7 | 73.4 | 8.2 | 73.6 | 8.2 |
| 60 | 40 | 0.78 | 75.8 | 8.7 | 73.4 | 8.5 | 73.0 | 8.5 | 71.9 | 8.3 |
| 40 | 60 | 1.77 | 78.2 | 8.7 | 73.8 | 8.7 | 72.6 | 8.7 | 70.2 | 8.7 |
| 40 | 60 | 1.77 | 80.1 | 8.3 | 74.4 | 8.6 | 71.2 | 8.7 | 69.4 | 8.6 |
| 20 | 80 | 4.71 | 80.6 | 7.1 | 77.4 | 7.1 | 74.5 | 7.2 | 72.6 | 7.4 |
| 20 | 80 | 4.71 | 80.1 | 7.2 | 76.6 | 7.3 | 74.0 | 7.4 | 70.7 | 7.5 |
| 0 | 100 | | 81.4 | 6.5 | 76.9 | 6.6 | 73.0 | 6.5 | 69.5 | 6.6 |
| 0 | 100 | | ... | ... | 76.5 | 6.5 | 73.2 | 6.5 | 70.2 | 6.5 |

Pulping Conditions

| | |
|---|---|
| Moisture-free wood chips consisting of equal weights of birch, beech, and maple from northern New York state | 100 g. |
| Total $Na_2O$ charge on weight of moisture-free wood | 12.2% |
| Liquor/wood ratio by weight | 5:1 |
| Maximum cooking temperature, 30 min. from room temperature to 100°C.; 120 min. from 100 to 175°C. | 175°C. |
| Cooking time at maximum temperature as indicated in table. | |

taining a constant charge of 25% on the weight of the wood ($NaHCO_3$ calculated as $Na_2CO_3$). At one hour pulping, liquor with a sulfite/carbonate ratio of about 2 was found to produce lower pulp yields than those with higher ratios, i.e., less carbonate.

Aronovsky and Gortner (*3*) explored the use of sodium carbonate as a pulping agent, using aspen sawdust. They stated that carbonate cannot be regarded as an inert pulping agent.

Keller and McGovern (*4*) investigated the effect of various buffers including sodium carbonate, bicarbonate, hydroxide, and sulfide. Cooking times at maximum temperature were reduced approximately 50% when the sulfite/carbonate ratio was lowered from 9 to 2.3 by the addition of carbonate. Pulps of similar yield from the two ratios showed little differences in chemical composition and strength.

Shimoda and Shindo (*5*) reported that the addition of sodium carbonate to a sodium sulfite pulping liquor accelerated the pulping of birch. They used weight ratios of sulfite/carbonate as low as 1 and cooked for 30 min. following a 100-min. temperature rise to 185°C.

## PROCEDURE

Mill-run chips of birch, beech, and maple were supplied by a northern New York paper company. These were mixed in equal quantities by weight. Cooks were made on a 100-g. scale, using miniature stainless steel bomb digesters rotated in a temperature-controlled oil bath, and on a 12-lb. scale using a 2-cu. ft. digester equipped with a circulating system and steam heat exchanger. All liquors were prepared by direct weighing of the dry chemicals, which were dissolved immediately before use. The same supplies of technical grade sodium sulfite and sodium carbonate were used for all cooks. All dilutions were made with city water. There was no re-use of spent liquor.

Cooks were first made in the miniature bomb digesters to study the effects on pulp yields when (1) sodium carbonate is added as a replacement for part of the sodium sulfite, and (2) when sodium carbonate is added as additional chemical.

In the first study, sulfite/carbonate ratios were varied on a molal basis with a constant charge of 12.2% $Na_2O$. Sulfite and carbonate were used in six combinations to include 100, 80, 60, 40, 20, and 0% of total sodium oxide as carbonate. Sulfite percentages equal the differences between carbonate percentages and 100%. A time series, in duplicate, of four cooks each was made on each of the six combinations. Pulping was effected by rotation of the bombs in a high-temperature glycol bath controlled by a cam-operated program-

**Table II. Neutral Sulfite Pulping of Mixed Hardwoods at Constant Sulfite Charge**

Miniature Digesters

| Cooking liquor: Weight ratio of sulfite/carbonate | Cooking liquor: Total $Na_2O$ in charge, % of Wood | Pulp yields and pH of blow liquor: Cooking, 1/2 hr. Yield, % | Cooking, 1/2 hr. Final pH | Cooking, 1 hr. Yield, % | Cooking, 1 hr. Final pH | Cooking, 1 1/2 hr. Yield, % | Cooking, 1 1/2 hr. Final pH | Cooking, 2 hr. Yield, % | Cooking, 2 hr. Final pH |
|---|---|---|---|---|---|---|---|---|---|
| 4.0 | 12.77 | 80.5 | 7.3 | 76.1 | 7.4 | 75.1 | 7.6 | 72.2 | 7.7 |
| 3.5 | 13.19 | 81.4 | 7.4 | 77.8 | 7.8 | 74.4 | 8.2 | 71.6 | 8.1 |
| 3.0 | 13.75 | 78.6 | 8.2 | 75.5 | 8.4 | 71.2 | 8.6 | 71.2 | 8.6 |
| 2.5 | 14.53 | 78.6 | 8.2 | 76.2 | 8.4 | 73.1 | 8.6 | 69.6 | 8.6 |
| 2.0 | 15.70 | 76.4 | 8.5 | 72.4 | 8.6 | 68.9 | 8.8 | 68.2 | 8.8 |
| 1.5 | 17.64 | 73.7 | 9.1 | 70.1 | 9.0 | 69.4 | 9.0 | 67.1 | 8.8 |
| 1.0 | 21.55 | 72.2 | 10.5 | 68.3 | 9.0 | 66.4 | 9.0 | 65.7 | 9.1 |

Pulping Conditions

| | |
|---|---|
| Moisture-free wood chips consisting of equal weights of birch, beech, and maple from northern New York state | 100 g. |
| $Na_2SO_3$ on weight of moisture-free wood | 20% |
| Carbonate used as indicated by weight ratio in table. | |
| Liquor/wood ratio by weight | 5:1 |
| Maximum cooking temperature, 30 min. from room temperature to 100°C.; 120 min. from 100 to 175°C. | 175°C. |
| Cooking time at maximum temperature as indicated in table. Initial pH of cooking liquor | 10.8–10.9 |

**Table III. Neutral Sulfite Pulping of Mixed Hardwood at Constant Sulfite Charge**

2-cu. ft. Digester

| Cooking data: Weight ratio of sulfite/carbonate | Cooking data: Time at max. temp., min. | Cooking data: Blow liquor pH | Cooking data: Sodium sulfite, g.p.l. | Data on unbeaten pulp: Pulp yield, % of wood | Data on unbeaten pulp: TAPPI K no. RC-242 % $Cl_2$ | Data on unbeaten pulp: Brightness, Hunter blue filter | Data on unbeaten pulp: Canadian Standard freeness | Fiber classification, per cent retained by screens with meshes indicated: +14 | 14–30 | 30–50 | 50–100 | −100 | TAPPI beater Test (T 200 + 205), Properties at Canadian Standard freeness shown: TAPPI burst factor 350 | 300 | TAPPI tear factor 350 | 300 | TAPPI breaking length, m 350 | 300 | Bulk, cc./g., 300 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 120 | 8.0 | 20.8 | 73.3 | 22.2 | 50.3 | 475 | 9.0 | 25.0 | 31.6 | 16.4 | 18.0 | 32 | 37 | 70 | 68 | 7100 | 7800 | 1.65 |
| 3 | 105 | 8.5 | 20.8 | 73.3 | 22.7 | 49.9 | 455 | 6.6 | 24.4 | 33.4 | 17.0 | 18.6 | 35 | 41 | 70 | 72 | 7300 | 7200 | 1.62 |
| 2 | 90 | 8.7 | 17.5 | 72.5 | 22.6 | 43.8 | 480 | 6.7 | 25.4 | 32.7 | 17.3 | 17.9 | 42 | 46 | 73 | 72 | 7500 | 8100 | 1.57 |
| 1 | 30 | 9.2 | 15.0 | 72.3 | 26.7 | 35.2 | 515 | 6.0 | 27.3 | 30.1 | 17.1 | 19.5 | 38 | 42 | 72 | 72 | 7000 | 7400 | 1.62 |

Pulping Conditions

| | |
|---|---|
| Moisture-free wood consisting of equal weights of birch, beech and maple from northern New York state | 12 lb. |
| Sodium sulfite on moisture-free wood | 20% |
| Ratio by weight liquid/wood (moisture-free) | 3.5:1 |
| Maximum cooking temperature, 30 min. from room temperature to 100°C.; 112½ min. from 100°C. to 175°C. | 175°C. |
| Heating by indirect steaming and liquor circulation | |

Pulp Processing

After cooking, chips were treated by:
1. Disintegrating for 10 min. with 6-in. Cowles impeller at 3600 r.p.m.
2. Passing through 8-in. Bauer refiner with plate no. 6945 at 0.001 in. setting.
3. Screening through 0.010-in. cut flat screen plate.

mer which regulated bath temperature by steam coils. Cooking conditions are presented in Table I. After disintegrating, thorough washing, and pressing, pulp yields were calculated from direct weighings of moisture-free pulp. The pH values were determined on the residual liquors.

To investigate the comparative strength properties of pulp made under high-yield continuous pulping conditions, climate a series of eleven 20-min. cooks were made in the 2-cu. ft. digester. To allow a rapid rise to maximum pressure, 3-lb. charges were used. The total sodium oxide charge was held constant at 10%, based on moisture free wood, and the amounts of carbonate and sulfite were varied from 0 to 100% in steps of ten percentage points. Cooking was by direct steam. Conditions of pulping and processing are shown in Table IV together with the test results on the pulps.

Again, using the miniature bomb digesters for a time series, a second study maintained a constant charge of 20% sodium sulfite, based on moisture-free wood, and varied the carbonate charge to provide sulfite/carbonate carbonate ratios, by weight, of 4, 3.5, 3, 2.5, 2, 1.5, and 1. Other cooking conditions were the same as those used in the first study and are given in Table II. Pulp yields and final pH values were also determined as in the first study.

From the data of the second series of miniature cooks, a plot of pulp yields versus cooking times was used to predict the cooking times required for obtaining similar pulp yields from cooks with constant sulfite charge at sulfite/carbonate ratios of 4, 3, 2, and 1. Using these anticipated cooking times, four cooks were made in the 2-cu. ft. digester, using 12-lb. charges of moisture-free wood. The temperature cycle was closely controlled by means of a cam and an automatic steam valve. Air was relieved in the early stages of the cook. Cooking conditions and pulp processing procedures are given in Table III. After processing, the pulps were evaluated for permanganate number, brightness, fiber classification, and TAPPI beaten strength values. These results are also shown in Table III.

## DISCUSSION

### *Constant Sodium Charge*
### (*All Percentages on a Molal Basis*)

Figure 1 illustrates the data from Table I as percentage pulp yields versus cooking time at a maximum temperature of 175°C. For the first ½ hr. at that temperature, the lowest yields were reached with combinations of carbonate and sulfite rather than with 100% sulfite or 100% carbonate. For 2 hr. at temperature, the

**Table IV. Neutral Sulfite Pulping of Mixed Hardwoods at Constant Total Sodium Charge**

2-cu. ft. Digester

| Cooking data: Total $Na_2O$, % as $Na_2CO_3$ | Cooking data: $Na_2O$, % as $Na_2SO_3$ | Cooking data: Weight ratio of sulfite/carbonate | Cooking data: Blow liquor pH | Cooking data: Blow liquor Sodium sulfite, g.p.l. | Data on unbeaten pulp: Total pulp yield, % of wood | Data on unbeaten pulp: Combined rejects, % of pulp | Data on unbeaten pulp: TAPPI K no. RC-242, % $Cl_2$ | Data on unbeaten pulp: Brightness, Densichron blue filter | Data on unbeaten pulp: Canadian Standard freeness | Data on beaten pulp, TAPPI Beater Test (T 200 + 205), Properties at beaten freeness: Beating time, min. | Beaten freeness, Canadian Standard | TAPPI burst factor | TAPPI tear factor | TAPPI breaking length, m. | Bulk, cc./g. | Concora crush resistance,[b] lb. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 0 | 0 | 9.4 | 0 | 84.6 (82.6)[a] | 11.9 | 29.4 | 13.8 | 645 | 40 | 310 | 31.2 | 68.5 | 5750 | 1.75 | 77.2 |
| 90 | 10 | 0.13 | 9.9 | 0 | 81.8 (81.2) | 14.8 | 30.6 | 15.0 | 675 | 50 | 300 | 32.8 | 68.9 | 5700 | 1.71 | 77.8 |
| 80 | 20 | 0.30 | 9.3 | 0.6 | 82.4 (79.9) | 10.3 | 10.3 | 15.7 | 580 | 35 | 285 | 29.6 | 65.8 | 5750 | 1.75 | 73.1 |
| 70 | 30 | 0.50 | 10.2 | 1.9 | 79.4 (78.5) | 12.8 | 28.9 | 18.5 | 625 | 36 | 310 | 28.8 | 61.0 | 5750 | 1.71 | 77.6 |
| 60 | 40 | 0.78 | 9.7 | 4.4 | 79.6 (83.1) | 13.6 | 27.5 | 20.5 | 680 | 48 | 295 | 33.6 | 65.3 | 6950 | 1.67 | 84.4 |
| 50 | 50 | 1.19 | 9.6 | 5.7 | 79.8 (80.9) | 12.5 | 27.2 | 23.0 | 630 | 34 | 305 | 36.5 | 67.5 | 6750 | 1.70 | 87.0 |
| 40 | 60 | 1.77 | 9.4 | 8.2 | 79.8 (81.7) | 14.1 | 25.1 | 23.0 | 675 | 46 | 300 | 35.5 | 64.7 | 6850 | 1.68 | 92.5 |
| 30 | 70 | 2.75 | 8.8 | 13.9 | 80.3 (79.5) | 13.1 | 26.9 | 26.0 | 525 | 33 | 295 | 36.3 | 65.0 | 6350 | 1.65 | 96.4 |
| 20 | 80 | 4.71 | 7.8 | 15.1 | 80.0 (83.4) | 12.6 | 25.9 | 27.0 | 660 | 45 | 290 | 38.4 | 68.7 | 7300 | 1.64 | 94.0 |
| 10 | 90 | 10.62 | 7.2 | 20.2 | 82.3 (82.8) | 11.9 | 25.2 | 29.0 | 665 | 36 | 300 | 38.0 | 70.0 | 7250 | 1.74 | 88.9 |
| 0 | 100 | ... | 6.6 | 22.7 | 80.3 (81.4) | 11.3 | 23.6 | 31.2 | 610 | 29 | 300 | 38.6 | 68.3 | 6800 | 1.70 | 84.5 |

Constant Cooking Conditions

| | |
|---|---|
| Moisture-free wood consiting of 50% maple and 25% each of birch and beech | 3 lb. |
| Sodium as $Na_2O$ on moisture-free wood | 10% |
| Ratio by weight liquid/wood (moisture-free) | 3:1 |
| Direct steaming to 150 p.s.i.g. | 5 min. |
| Direct steaming at 150 p.s.i.g. | 20 min. |
| Digester and liquor preheated prior to charging. | |
| No relief during cooking. | |

Pulp Processing

After cooking, chips were treated by:
1. Pressing out spent liquor in a cider press.
2. Disintegrating by one pass through an 8-in. Bauer refiner with plate no. 6945 at 0.001-in. setting.
3. Screening through 0.008-in. cut flat screen plate.
4. Centri-Cleaning in 3 stages in a 3-in. Bauer Centri-Cleaner.
5. Beating to approximately 300 Canadian Standard freeness in a Valley beater

[a] Figures in parentheses are check yields on duplicate cooks.
[b] Concora tests are average of 15 strips from five test sheets (26 lb./1000 sq. ft.) made by TAPPI Standard T 205.

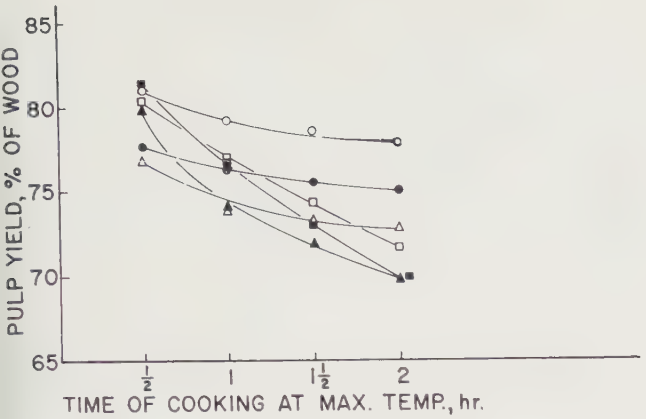


*Fig. 1. Effect on pulp yields due to varying sulfite/carbonate ratios when sodium charges are constant*

○—100% $Na_2CO_3$ 0% $Na_2SO_3$, molal basis
●—80% " 20% "
△—60% " 40% "
▲—40% " 60% "
□—20% " 80% "
■— 0% " 100% "

lowest yields were obtained with 100% sulfite and with the combination of 60% sulfite and 40% carbonate. For a quick cook such as used for corrugating medium, a combination of the two chemicals is indicated for fastest pulping. For cooks of longer duration, combinations with the greater percentage chemical as sulfite are indicated.

The slopes of the curves in Fig. 1 represent relative pulping rates. As indicated by their steeper slopes, the pulping rates, after the first $^1/_2$ hr., are shown to be greater for the liquors containing the major percentage of chemical as sulfite.

Figure 2 presents the data from Table I as time-interval curves showing the effect of liquor composition on the resulting pulp yields for each time interval. The $^1/_2$- and 1-hr. curves show fairly well-defined dips near the 50% sulfite point, again indicating this combination as an efficient pulping agent for a short cook. The $1^1/_2$-hr. curve and the 2-hr. curve both flatten near the 50% sulfite point, indicating that for longer cooks, a liquor of 60% sulfite might be utilized. The pulp and paper qualities obtained would, of course, be the decisive factor in justifying charges with higher percentages of carbonate.

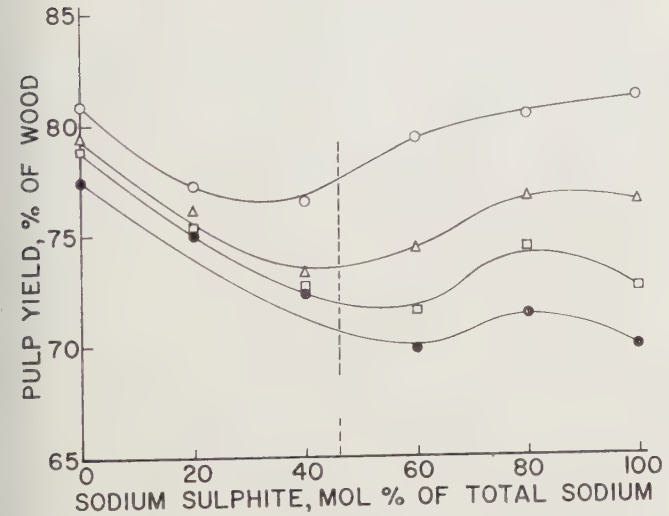


*Fig. 2. Pulp yields vs. mole % sodium sulfite based on constant sodium charges*

Dashed vertical line indicates
$Na_2SO_3$:$Na_2CO_3$ = 1:1 wt. ratio
○—$^1/_2$ hr. cooking
△—1 " "
□—$1^1/_2$ " "
●—2 " "

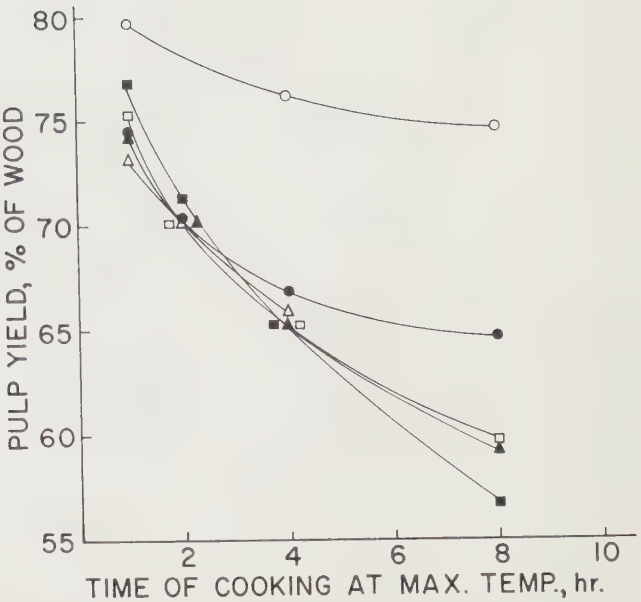


*Fig. 3. Effect on pulp yields of varying sulfite/carbonate ratios when total chemical charges are constant (Bray and Eastwood data)*

○—100% $Na_2CO_3$
●—1:1 $Na_2SO_3$:$Na_2CO_3$
△—2:1 " "
▲—3:1 " "
□—4:1 " "
■—100% $Na_2SO_3$

Figures 3 and 4 show graphs similar to Figs. 1 and 2 of the pulp yields obtained by Bray and Eastwood (*2*) from black gum sawdust. They used a constant total

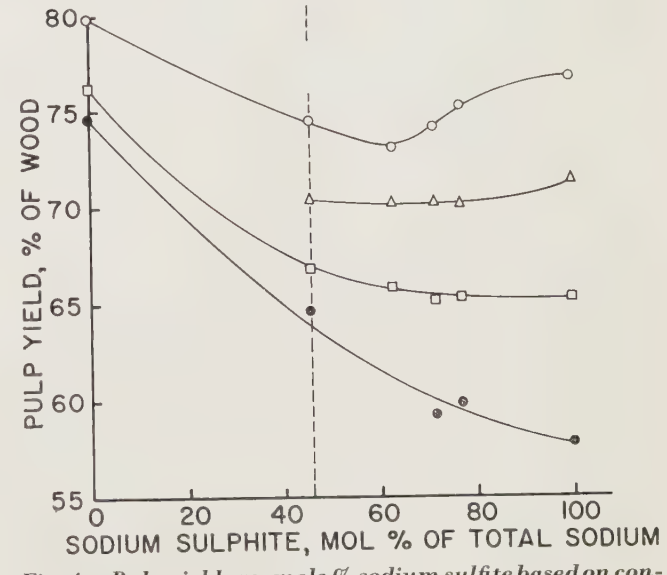


*Fig. 4. Pulp yields vs. mole % sodium sulfite based on constant weight charge (Bray and Eastwood data)*

Dashed vertical line indicates
$Na_2SO_3$:$Na_2CO_3$ = 1:1 wt. ratio
○—1 hr. cooking
△—2 " "
□—4 " "
●—8 " "

chemical charge of 25% sulfite and carbonate based on moisture-free wood, by weight, but with different ratios of the two chemicals. The first yields were taken after 1 hr. at 170°C. and confirm our findings. At 1 hr, the yields are shown to be lower for combinations of the two chemicals than for the individual chemicals. The flatter curves for 100% carbonate and for the sulfite/carbonate ratio of 1 also are similar to the results shown in Fig. 1. For the relatively long cooking time of 8 hrs, the lower pulp yields show the liquors with the higher percentages of sulfite to be the most effective pulping agents.

Figure 4 is a graph of Bray and Eastwood's data which corresponds to the Fig. 2 graph of the data in Table I. Curves of similar shape are noted in the two graphs, and maximum pulping efficiencies are indicated at around 60 to 70% sodium sulfite.

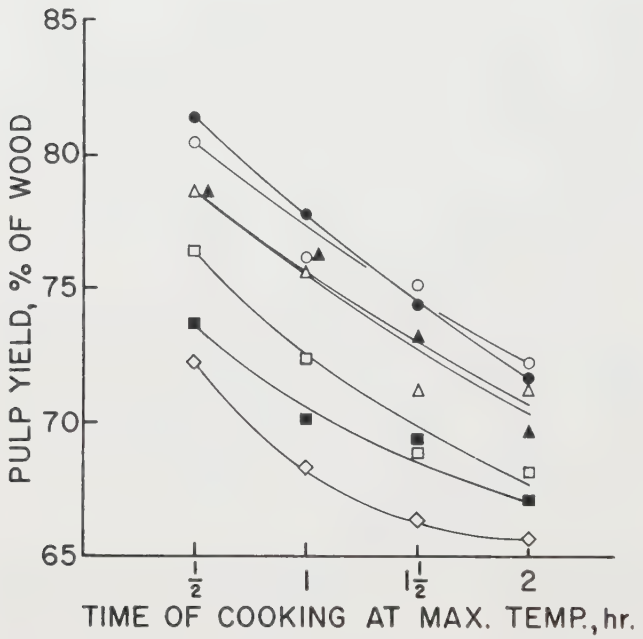


*Fig. 5. Effect on pulp yields due to carbonate addition when sodium sulfite charges are constant*

○—4.0:1 $Na_2SO_3$:$Na_2CO_3$ wt. basis.
●—3.5:1 " "
△—3.0:1 " "
▲—2.5:1 " "
□—2.0:1 " "
■ —1.5:1 " "
◇—1.0:1 " "

The results of the direct steamed cooks are given in Table IV. These cooks, at 11 different sulfite/carbonate ratios, provided sufficient pulp for strength evaluations. With the exception of the 100% $Na_2CO_3$ cook, the yields for all combinations are the same within experimental error. Yield checks on duplicate cooks are shown in parentheses. Because of the greater difficulties in precisely controlling direct steamed cooks of short duration, these yield figures do not check as closely as those for the small-scale cooks.

Strength tests on the direct steamed cooks showed that burst, tensile, and crush resistance values reached their highest values after the sulfite content exceeded 50% on a molal basis. Beating times required to reach 300 Canadian Standard freeness in the laboratory Valley beater did not show any distinct trends.

For high-yield semichemical pulps, such as used for corrugating medium, a sulfite/carbonate ratio of 1 appears to be acceptable. For paper grades, the higher brightnesses resulting from greater amounts of sulfite, would have to be considered. TAPPI permanganate numbers (RC-242) show steadily decreasing values as sulfite content is increased. Liquors of the highest sulfite content produced pulps with the lowest chemical requirements for bleaching.

### *Constant Sulfite Charge*

### (*All Sulfite/Carbonate Ratios on a Weight Basis*)

The second yield study of miniature cooks was made with a constant charge of sulfite, and the carbonate content was varied to provide seven different ratios of sulfite/carbonate on a weight basis (see Table II).

In Fig. 5, the resulting pulp yields are plotted against cooking time for each ratio. As the weight ratio of sulfite/carbonate was progressively reduced by carbonate additions, lower yields were obtained. The similar slopes of the curves for the different ratios show that the pulping due to additional carbonate is most effective during the first ½ hr.

For pulp quality comparisons, at equivalent yields, four cooks were made in the 2-cu. ft. digester at sulfite/carbonate ratios of 4, 3, 2, and 1. The pulping times, at temperature, to reach like yields, were estimated from Fig. 5. Times at temperature were progressively lowered from 120 min. to 105, 90, and finally 30 min. as sulfite/carbonate ratios were lowered from 4 to 3, 2, and 1 by carbonate addition. With the exception of the sulfite/carbonate ratio of 2, these times were predicted by the small-scale cooks. All four cooks approximated 73% yields. These pulps were evaluated for physical properties and were found to be quite similar with respect to fiber classification, burst, tear, tensile, and bulk (see Table III). Brightness dropped progressively with higher carbonate content, i.e., lower sulfite/carbonate ratios. The permanganate number was appreciably higher in the case of a sulfite/carbonate ratio of 1.

## SUMMARY

In addition to its corrosion-inhibiting properties, sodium carbonate must be considered an effective pulping agent when used in combination with sodium sulfite in the neutral sulfite process. For quick cooks of less than 1 hr., sulfite/carbonate ratios as low as 1 provide opportunities for savings in sulfur. For bleachable-grade pulps, additions of carbonate to provide sulfite/carbonate ratios of 2 and 3 can shorten cooking times without appreciably affecting pulp qualities.

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# Dissolving Pulps from Domestic Timber Bamboo—*Phyllostachys bambusoides*

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**Dry, mature timber bamboo—*Phyllostachys bambusoides*—was investigated as a raw material for the preparation of dissolving-grade pulps by prehydrolysis, sulfate-pulping techniques. The condition of the raw material and the variables in the hydrolytic treatment were studied for their influence upon the yield and characteristics of the pulps when the pulping and bleaching conditions were kept constant. Nitric acid, steam, and water were used as the hydrolytic agents. Pulps obtained under a number of combinations of these variables had chemical and physical characteristics in the range of those of commercial cellophane, textile, and medium-tenacity grades of dissolving pulps from woods. One satisfactory hydrolytic technique involved cooking with 6% nitric acid (basis chips) at 140°C. for 30 min. with chips being collected between screens having 1/2- and 3/4-in. diameter openings. Hydrolyses with steam and water at 180°C. gave comparable yields and properties, except that the disperse viscosity values were lower. Yields of pulps ranged from 23 to 32%. Further evaluation of bamboo pulps by actual conversion to viscose-derived products appears warranted.**

For many years bamboos have been used commercially in Eastern and Southern Asia, and in the East Indies as raw material from which to produce paper (*1, 2*). The conditions and techniques employed in some instances are considered primitive and uneconomical when compared with American manufacturing practices. A fast-growing cellulosic crop, such as bamboo, has potential as a raw material in the expanding pulp industry in the United States. Bamboo possesses further attributes as a good yielder of cellulose, and a crop adaptable to production on approximately 50 million acres of land extending south from South Carolina and westward along the Gulf into Texas (*3*). In 1907 Raitt (*4*) claimed that in Burma by harvesting at 3-year intervals bamboo would yield 5 tons of solids per acre per year. In April, 1959 Ueda estimated that in India 3 tons of airdry culms per acre per year could be realized if harvesting were done on an annual basis (*5*). Accurate appraisals of productivity on a sustained basis in the United States are now in progress by the United States Department of Agriculture.

Bamboos occur as two general types—the running and the clump-forming. The former are hardier and will grow almost anywhere that the temperature does not fall below 5°F.; this is the type considered for propagation and use in this country.

In 1935 bamboo was suggested as an industrial crop for the United States when R. A. McClure (*6*), then an agricultural explorer for USDA, speculated on its future as a pulping raw material in the United States. The Department's interest was subsequently shown by contracts negotiated between the Plant Introduction Section of the Crops Research Division and the Herty Foundation Laboratory (*7*) to evaluate a number of bamboos in papermaking operations. These bamboos were grown at the USDA Barbour Lathrop Plant Introduction Gardens near Savannah, Ga. About 20 species were used in producing coarse wrapping papers and high-grade bleached papers (*8*). Applicability of bamboo for the production of high alpha-cellulose content dissolving pulps was not investigated at that time. However, results of the investigations contributed in a large measure to selection of *Phyllostachys bambusoides* as the specie for evaluation at the Northern Laboratory as raw material from which to prepare dissolving-grade pulps.

Several methods used in the commercial production of pulps for paper, such as the "overhead" or single-stage and the "fractional" or two-stage, could be used to prepare pulps from bamboo; however, the resulting pulps generally contained more pentosans and ash than can be tolerated in viscose manufacture.

In a survey of cellulose-bearing materials in India, Ahmad and Karnik (*10*) applied Raitt's fractional pulping technique (*9*) to several species of bamboo. Neither disperse-viscosity values nor pentosan values were reported for the pulps; residual ash contents were high and alpha-cellulose low in comparison with present-day dissolving pulp characteristics. Subsequently Karnik and Sen (*11*) employed undisclosed quantities of hydrochloric acid for prehydrolysis to reduce ash contents of bamboo pulps. Although yields of 35 to 39% were reported, the alpha-cellulose contents did not exceed 86%. Gohel and Thoria (*12*) used water and steam as hydrolytic agents in a prehydrolysis-sulfate technique with an unidentified market bamboo from Calcutta to prepare a high-quality dissolving pulp. These various investigations were made with Indian bamboos. Because they differ in characteristics from those grown in the United States similar behavior on pulping should not be expected.

Bamboo pulp considered suitable for manufacture of high-grade papers and rayon in the United States was reported by Hong Lau (*13*) in 1941. He used two species—*Bambusa tulda* and *P. bambusoides*—both grown on an experimental basis in southeastern United States. In his studies he used a hydrotropic solvent (sodium xylenesulfonate) on the culms, including nodes, to prepare pulps with alpha-cellulose contents of 93% and with pentosan contents of 5 to 8%. Later in studies at the New York State College of Forestry Joglekar and Donofrio (*14*) used sulfuric acid for prehydrolysis preceding kraft digestion and bleaching to prepare dissolving pulps from an unidentified species of

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bamboo (3.25 in diam., probably *Bambusa vulgaris*) grown in Florida. Pulps were of high quality although the yields were low and ash contents were greater than those of current commercial pulps.

Because of the relatively high pentosan content of *P. bambusoides*, the prehydrolysis-sulfate process was selected for the present study. According to Richter (*15*) the hydrolytic treatment tends to break or weaken, with minimum degradation of the alpha-cellulose constituent, any chemical or physical bonds that might exist between the alpha-cellulose and the noncellulosic constituents in plant materials. Steam, water, and nitric acid were selected as the hydrolytic agents.

This investigation concerns a study not only of variables in the mechanical preparation of bamboo (*P. bambusoides*), but also of hydrolyses by nitric acid, water, and steam. Pulps from hydrolyzed materials digested with kraft chemicals were bleached in a seven-stage treatment. Influence of the various preparatory treatments upon yield and characteristics of pulps was determined.

## EXPERIMENTAL

### *Materials*

Culms of *P. bambusoides* cut into 4-ft lengths were obtained from the Department's Barbour Lathrop Plant Introduction Garden, Savannah, Ga., in the spring of 1957. These culms were from a random harvest late in 1956 and were up to 15 years of age. After receipt at the Northern Laboratory the culms were stored out of doors 4 months before use.

Several methods for preparing bamboo for pulping were investigated: Crushing "as received" or after extended soaking in water; shredding in a double-disk refiner or in a Rotopulper*; chipping with a 24-in. diam. two-knife chipper; planing bamboo culms to form shavings approximately $^1/_{32}$-in. thick; and sawing to pieces of specific lengths.

Culms to be crushed were split before being passed between the rolls of a sugarcane mill. The crushed material was passed through a rotary cutter to reduce the material to about 1 $^1/_4$-in. lengths.

For shredding, culms were sawed into 2-in. lengths. These sections were passed through a double-disk mill fitted with waveline plates and later with "devil" or "spike-tooth" plates. Similar sections from freshly cut green culms, obtained from the Barbour Lathrop Garden, as well as culms from the original harvest, were passed through a Rotopulper located at the University of Florida.

To study the influence of particle size on penetration by the hydrolytic agent, bamboo culms were sawed into $^1/_2$- and $^1/_4$-in. lengths and then the segments were cut into squares. In some instances the culms were first separated into two groups having an average wall thickness of either $^3/_{32}$ or $^5/_{32}$ in.

Chips produced with the two-knife laboratory chipper were screened, and the fraction, collected between screens having $^1/_2$- and $^3/_4$-in. round openings, was recovered for experimental pulping. This screened fraction, amounting to about two-thirds of the bamboo chipped, contained some slivers and particles having lengths appreciably larger and smaller than the dimensions of the screen openings. In spite of the variation in particle size these chips, for reason of convenience, are designated as $^1/_2$- to $^3/_4$-in. chips. Except for investigating the effect of size and shape on yield and quality of pulp, these chips were used in the hydrolyses.

For comparative purposes eight samples of commercial dissolving pulps prepared by the prehydrolysis-sulfate treatment of wood were obtained and analyzed. The pulps had already been designated by the producers as medium tenacity, textile, and cellophane-grade pulps.

### *Pulp Preparation*

*Hydrolyses.* Both nitric acid and water hydrolyses were performed in a 2-liter stainless-steel reaction vessel having a stirrer and an electrical heating jacket. A stainless-steel screen with $^3/_{32}$-in. diam. perforations was placed 1 in. above the stirrer to prevent chips from interfering with the stirrer and to prevent disintegration of chips. After the bamboo chips were placed in the reactor, a circular stainless-steel plate kept the chips immersed in the hydrolyzing medium. Charges consisted of 150 g. of air dry chips, the required amount of nitric acid, and sufficient water to provide a 10:1 liquid-solids ratio. Reproducible heating of the reactor and its contents was achieved with automatic control at a precision of $\pm 1°C$. At the end of the heating period, the reactor was removed from the heating jacket and cooled rapidly to 38°C. with tap water before opening.

The cooked chips were drained substantially free from the acidic hydrolysis liquors and then were subjected to four cycles of steeping and filtration to remove acids from the interior. A cycle consisted of suspending wet solids in 1.5 liters of distilled water, stirring continuously for 15 min., filtering, and then washing the solids with 0.25 liter of water. After the final washing the hydrolyzed materials without drying were ready for pulping. Nitric acid-hydrolyzed chips when so indicated in the tables were passed through a single-disk mill having devil-tooth plates prior to the steeping-filtration treatment. This milling broke down fiber bundles to aid in subsequent removal of acid from the fibers.

Adequacy of the milling-steeping-filtration technique for removal of acid from hydrolyzed materials was appraised by determining the amounts of acid actually removed in the various processing stages. This appraisal was done with three hydrolyses performed for 30 min. at 140°C. with 6% nitric acid based on chips. Total acid contents of liquors from the initial hydrolysis, the milling phase, and the seven steeps were determined. Results disclosed that 78 to 84% of the total titratable acidity was removed during initial draining of the hydrolyzates, that the gross was increased to 95 to 97% by milling, and that 99.5% of the acid was accounted for at the end of four steeps. Extractions by remaining three steeps amounted to 0.5%, a value considered not worth attempting. Total acidity following hydrolyses ranged from 177 to 198% of the nitric acid equivalents added originally because of formation of acidic products in the process.

When pretreatments were desired prior to hydrolyses to improve penetration, the contents of the reactor were

* This and all subsequent references to commercial firms or to equipment by specific names are made for clarity and conciseness of presentation and are not to be construed as endorsements or recommendations by the United States Department of Agriculture.

**Table I. Comparative Composition of Timber Bamboo and Selected Soft and Hardwoods**

| Material analyzed | Alpha[a] cellulose, % | MEA[b] cellulose, | Pentosan, % | Lignin,[c] % | Ash, % | Solubility in: Hot water, % | 1% Sodium hydroxide, % | Alcohol benzene, % | Ether, % |
|---|---|---|---|---|---|---|---|---|---|
| Timber bamboo | 34.8 | 58.1 | 28.5 | 23.0 | 2.3[d] | 7.8 | 26.7 | 4.4 | 0.72 |
| Softwood (spruce) | 39.4 | 60.0 | 10.6 | 27.6 | 0.5 | 3.6 | 13.9 | 2.4 | 0.42 |
| Hardwood (maple) | 39.1 | 60.2 | 22.6 | 23.3 | 0.5 | 2.3 | 15.7 | 2.4 | 0.32 |

[a] Free from ash and pentosan.
[b] Monoethanolamine (MEA) method of Nelson and Leming (*20*).
[c] Method of Aronovsky, Nelson, and Lathrop (*21*).
[d] Silica content 0.14%, basis original material.

subjected to alternate vacuum, vacuum-pressure, or pressure treatments at room temperature before the hydrolyses.

Other variables studied were particle size, hydrolysis temperature, and the hydrolysis time.

Hydrolyses by steam were performed in a stainless-steel digester tumbling at 1 r.p.m. Five pounds of air-dry chips were placed in the digester, water was added to raise the moisture content to 60%, and the mass was tumbled for 1 hr. then subjected to direct steaming at 180° or 190°C. for the desired time. Before pulping was performed, the hydrolyzed chips were washed repeatedly with tap water without removal from the digester.

*Pulping.* All pulping, except as noted below, was performed in the 2-liter reaction unit described. Conditions for pulping consisted in cooking hydrolyzed material for 2 hr. at 170°C. with 18% kraft chemicals ($NaOH:Na_2S$:2:1) based on dry bamboo prior to hydrolysis. A liquid-solids ratio of 5:1 was used in all digestions. Digested materials were washed essentially free of cooking liquor with distilled water, dispersed in deionized water for 3 min. in a British disintegrator to defiber the pulp, and then screened through an 8-cut flat screen preparatory to bleaching. Deionized water was used for the screening.

Materials steam-hydrolyzed in the tumbling digester were subjected to kraft cooking in the same tumbling unit.

While the amount of pulping chemicals, basis original bamboo solids, was kept constant throughout the study, the ratio of chemicals-to-hydrolyzed solids varied with the severity of the prior hydrolytic treatment. Approximate yields of hydrolyzed solids and chemical-to-solids ratios for some of the hydrolysis conditions are indicated below:

| Conditions | Yields, % | Chemical-solids ratio, % |
|---|---|---|
| 6% acid, 30 min., 120°C. | 76 | 23 |
| 6% acid, 30 min., 140°C. | 68 | 26 |
| Steam, 15 min., 190°C. | 68 | 26 |

The greater ratio of pulping chemical-to-hydrolyzed solids could account, in part, for lower yields of pulp when the more drastic hydrolytic treatments were used.

All experimental pulps were prepared from hydrolyzed materials by cooking with kraft chemicals and bleaching under the same conditions. Only in the precooking phases (i.e., material preparation, impregnation, hydrolyses, milling, and washing) did conditions differ. Therefore, to avoid unnecessary repetition and confusion in subsequent discussion, the influence of of preparatory and hydrolytic treatments on final pulps is evaluated without further reference to the pulping and bleaching phases.

*Bleaching.* All pulps were bleached by the same seven-stage treatment at 3% consistency. Chemicals used were based on ovendry weight of the pulp. Each pulp was washed to a pH of approximately 7.0 after each stage. The method used was that described by Locus (*16*).

***Characterization of Raw Materials Plus Commercial and Experimental Pulps.***

The original bamboo, maple and spruce woods, representative commercial pulps, and the experimental pulps were characterized according to TAPPI Standard Methods (*17*) and other recognized procedures as indicated. Determination of cupriethylenediamine

**Table II. Influence of Particle Size and Shape on Characteristics of Bleached Sulfate Pulps Prepared from *P. bambusoides***
30-min. Hydrolysis with 6% Nitric Acid at 120°C.

| Pulp no. | Pretreatment[a] | Thickness, in. | Yield, % | Alpha-cellulose, % | Beta-cellulose, % | Pentosans, % | Disperse viscosity,[b] cp. | Brightness (Hunter), % | Ash, % | Ether solubles, % |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | ½ to ¾ in. Random Chips | | | | | | |
| 1 | Yes | ... | 30.5 | 95.1 | 2.6 | 5.5 | 19.1 | 85.2 | 0.15 | 0.1 |
| 2[c] | Yes | ... | 26.0 | 96.2 | 2.3 | 2.7 | 13.8 | 86.3 | 0.17 | 0.3 |
| | | | | ½ by ½ in. Particles | | | | | | |
| 3 | Yes | 5/32 | 33.6 | 95.8 | 3.4 | 8.1 | 23.2 | 87.0 | 0.15 | ... |
| 4 | Yes[d] | 5/32 | 32.3 | ... | ... | 6.9 | 26.1 | 84.1 | ... | ... |
| 5 | Yes | 5/32 | 34.6 | 95.2 | 4.2 | 7.3 | 22.9 | 86.4 | 0.20 | 0.4 |
| 6[c] | Yes | 5/32 | 30.3 | 96.9 | 2.5 | 3.2 | 15.9 | 87.8 | 0.11 | 0.1 |
| | | | | ¼ by ¼ in. Particles | | | | | | |
| 7 | Yes | 5/32 | 34.2 | 95.4 | 3.2 | 6.3 | 21.3 | 87.4 | 0.16 | ... |
| | | | | Crushed and Chopped to 1¼ in. | | | | | | |
| 8 | No | ... | 35.7 | 95.4 | 4.9 | 10.8 | 35.3 | 73.6 | 0.39 | 0.2 |
| | | | | Planer Shavings | | | | | | |
| 9 | No | 1/32 | 29.8 | 96.2 | 2.8 | 4.4 | 17.7 | 86.8 | 0.16 | 0.2 |

[a] Impregnation pretreatment with acid: 50 cycles of vacuum to 22-in. mercury and release to atmosphere, 1 min. per phase.
[b] Pulp at 0.5% concentration in cupriethylenediamine.
[c] Hydrolysis for 30 min. at 140°C.
[d] Double treatment with intervening overnight steep at room temperature.

Table III. Influence of Hydrolytic Conditions and Milling on Characteristics of Bleached Sulfate Pulps Prepared from 1/2- to 3/4-in. Bamboo Chips

| Pulp no. | Pre-treatment[a] | Hydrolytic agent | Hydrolysis: Time, min. | Hydrolysis: Temp., °C. | Yield, % | Alpha-cellulose, % | Beta-cellulose, % | Pentosans, % | Disperse viscosity,[b] cp. | Brightness (Hunter), % | Ash, % | Ether solubles, % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **No Milling after Hydrolysis** | | | | | | | | | | | | |
| 10 | No | $HNO_3$—6% | 30 | 120 | 34.4 | 92.7 | 2.8 | 10.0 | 33.2 | 56.8 | ... | ... |
| 11 | Yes | $HNO_3$—6% | 30 | 120 | 32.7 | 95.6 | 1.9 | 5.4 | 23.8 | 82.2 | ... | 0.4 |
| 12[c] | Yes | $HNO_3$—6% | 30 | 120 | 33.2 | 96.7 | 3.4 | 5.4 | 16.0 | 85.2 | ... | 0.4 |
| 13 | No | $HNO_3$—6% | 60 | 120 | 31.8 | 94.8 | 2.8 | 4.7 | 12.0 | 85.2 | ... | ... |
| 14 | No | $HNO_3$—6% | 30 | 140 | 27.7 | 94.9 | 2.7 | 3.3 | 10.3 | 83.7 | 0.05 | 0.3 |
| 15 | No | Steam | 15 | 190 | 28.2 | 95.5 | 2.0 | 4.0 | 11.6 | 81.7 | 0.23 | 0.1 |
| 16 | No | Steam | 60 | 180 | 27.1 | 94.9 | 4.0 | 3.9 | 6.1 | 83.7 | 0.30 | 0.1 |
| 17 | No | Water | 30 | 170 | 38.6 | 94.3 | 6.6 | 14.7 | 38.9 | 60.5 | 0.13 | ... |
| 18 | No | Water | 60 | 170 | 35.8 | 95.3 | 4.3 | 9.4 | 23.9 | 84.1 | 0.15 | ... |
| 19 | No | Water | 60 | 180 | 26.5 | 95.4 | 3.8 | 4.4 | 7.0 | 86.7 | 0.12 | 0.2 |
| 20 | No | Water | 30 | 190 | 24.8 | 95.5 | 3.7 | 2.1 | 6.6 | 86.2 | 0.13 | 0.1 |
| **Chips Milled after Hydrolysis** | | | | | | | | | | | | |
| 1 | Yes | $HNO_3$—6% | 30 | 120 | 30.5 | 95.1 | 2.6 | 5.5 | 19.1 | 85.2 | 0.15 | 0.1 |
| 21 | No | $HNO_3$—6% | 60 | 120 | 29.3 | 96.4 | 3.0 | 4.3 | 16.5 | 88.9 | 0.10 | 0.0 |
| 22 | Yes | $HNO_3$—6% | 60 | 120 | 28.9 | 95.8 | 4.0 | 6.0 | 20.5 | 87.7 | ... | 0.3 |
| 23 | No | $HNO_3$—6% | 30 | 140 | 27.0 | 95.4 | 2.4 | 3.0 | 12.6 | 80.6 | 0.16 | 0.2 |
| 2 | Yes | $HNO_3$—6% | 30 | 140 | 26.0 | 96.2 | 2.3 | 2.7 | 13.8 | 86.3 | 0.17 | 0.3 |
| 24 | No | $HNO_3$—6% | 45 | 140 | 26.6 | 97.1 | 3.1 | 2.6 | 12.2 | 89.1 | 0.12 | 0.2 |
| 25 | No | $HNO_3$—6% | 60 | 140 | 24.0 | 94.4 | 4.9 | 2.5 | 7.8 | 87.4 | 0.16 | 0.2 |
| 26 | No | $HNO_3$—6% | 30 | 150 | 23.2 | 94.8 | 4.7 | 3.2 | 9.6 | 87.9 | 0.19 | 0.2 |
| 27 | No | $HNO_3$—8% | 30 | 140 | 24.4 | 94.9 | 3.8 | 2.7 | 10.5 | 87.3 | 0.14 | ... |
| 28 | No | $HNO_3$—8% | 60 | 140 | 23.4 | 94.5 | 5.0 | 2.4 | 7.4 | 87.7 | 0.16 | 0.2 |

[a] Impregnation pretreatment with acid: 50 cycles of vacuum to 22 in. mercury and release to atmosphere, 1 min. per phase.
[b] Pulp at 0.5% concentration in cupriethylenediamine.
[c] Pressure to 90 p.s.i. instead of vacuum used in impregnation pretreatment.

(CED) disperse viscosity values was according to the TAPPI procedure as modified by Lindsley (*18*). Beta-cellulose was determined gravimetrically according to the procedure of Cross and Bevan (*19*).

Data obtained represent preparatory conditions and average characteristics for pulps resulting from one to four replicated treatments at each condition.

## RESULTS AND DISCUSSION

Analytical data for *P. bambusoides*, spruce wood, and maple wood presented in Table I indicate that a reasonable yield of dissolving pulp might be anticipated from the bamboo. The pentosan value for bamboo is considerably higher than found for the woods, suggesting that the conditions needed for hydrolysis might be more severe than normally employed for the woods.

*Size Reduction of Culms Before Hydrolysis.* Alternative procedures for mechanical preparation of culms for processing included chipping, planing, crushing, and sawing to particles as shown in Table II. These experiments involving different particle types and sizes were performed under hydrolysis conditions which, as discussed in succeeding sections, are marginal for preparing good dissolving pulps of low pentosan content, but which are adequate for preparing pulps having alpha-cellulose contents exceeding 95%.

No essential differences resulted from the use of culm particles differing either in nominal thickness (pulp no. 3 vs. 5) or in length (pulp no. 7 vs. 3 and 5). These observations agree with Deshpande's claim (*22*) that there is no penetration of liquors through the epidermis and that vertical or longitudinal penetration is also slow because of the dense structure of the bamboo. However, contrary to Deshpande's conclusions, in our experience crushing did not facilitate penetration. Crushing culms followed by cutting them to about $1^1/_4$-in. lengths did not appear to offer any advantages; in fact, values for yield, disperse viscosity, and pentosans were unusually high. Because of these results and the inconvenience of crushing and cutting, further tests with crushed materials were discontinued. This action was consistent with the current trend in India where chipping is displacing the crushing operation in bamboo pulp mills (*5*).

Of the various bamboo particles used in 30-min. hydrolyses with 6% nitric acid at 120°C., planer shavings without pretreatment gave the best results (pulp no. 9). Pentosan content was reduced to 4.4% while the yield of purified pulp was 29.8% and the disperse viscosity was 17.7 cp. Planing, however, does not appear to be a practical procedure for commercial operation.

The ease and practicality of obtaining the $^1/_2$- to $^3/_4$-in. random chips, combined with their adequate performance in processing, account for our selecting them for use in the remainder of this study. We believe that some mechanical loosening or disruption of the bamboo structure may occur in the chipping process. Cracks and disrupted bundle sheaths that may be present in chips are of course not evident from a tabular presentation of data based on particle dimensions alone. Their existence, however, would explain the superiority of chips over sawed squares as a pulping raw material.

*Chip Pretreatment Prior to Hydrolysis.* Shortly after beginning the study it was seen on breaking chips after the hydrolysis treatment that diffusion of nitric acid through some was incomplete. It was also noted that results of the chemical analyses of pulps for several replicated treatments showed considerable variation. As possible means for improving penetration and diffusion, chips were subjected prior to hydrolysis either to repeated cycles of vacuum or pressure of 90 p.s.i. followed by release to the atmosphere.

The results as shown in Table III indicate that under marginal conditions of hydrolysis the pretreatment procedure can be used to substantial advantage in improving pulp properties (compare pulps nos. 11 and 12 with 10). On the other hand under more adequate conditions of operation the pretreatment procedures were

Table IV. Comparison of Properties of Experimental Bamboo Pulps with Three Grades of Commercial Prehydrolysis-Sulfate Dissolving Pulps from Wood

| Commercial pulp grade[a] | Comparable experimental pulps from Tables II and III, no. | Commercial dissolving pulps, range of values: Alpha-cellulose, % | Beta-cellulose, % | Pentosans, % | Disperse viscosity, cp. | Brightness, % | Ash, % | Ether solubles, % |
|---|---|---|---|---|---|---|---|---|
| Intermediate tenacity (3) | 2, 6, 14, 23 | 94.4–96.8 | 1.3–3.5 | 3.1–3.7 | 5.0–9.3 | 86.0–89.0 | 0.09–0.15 | 0.2 |
| Textile (3) | 15, 21 | 94.5–95.5 | 2.4–3.8 | 2.9–4.4 | 5.0–5.5 | 83.0–90.0 | 0.11–0.15 | 0.1 |
| Cellophane (2) | 1, 8, 13, 16, 19, 20, 25, 26, 27, 28 | 92.9–94.2 | 3.5–5.2 | 3.5–6.5 | 4.1–4.9 | 83.9–84.7 | 0.17–0.21 | 0.1–0.2 |

[a] Numbers in parenthesis under pulp grade indicate the number of commercial pulps characterized.

completely ineffectual and unnecessary (pulp no. 22 vs. 21 and pulp no. 23 vs. 2). From a practical viewpoint it is unlikely that such marginal conditions would be used in commercial operations. The vacuum and pressure treatments have significance only in this laboratory study of variables.

*Nitric Acid Hydrolyses.* The effects of varying time, temperature, and acid-to-chips ratio during hydrolyses on the yields and properties of pulps were studied. The expected general trends were observed; that is, as conditions became more drastic by use of longer time, higher temperature of hydrolysis, or more acid, pulps of greater purity resulted at some expense to the yield and degree of polymerization of the cellulose. Thus, in selection of operating conditions a compromise must be chosen depending upon the purity of product required and the prevailing economics.

Preparations resulting from hydrolyses at 120°C. were characterized especially by their relatively high disperse viscosities and pentosan contents. Alpha-cellulose was usually of the order of 95%. Yields ranged from about 29 to 36%. An increase in hydrolysis time from 30 to 60 min. at this temperature has a marked effect on pulps only if there are no pretreatments before hydrolyses and no milling after the hydrolyses. The marginal temperature for effective hydrolysis can be considered as 120°C.

At 140°C. products of almost equivalent characteristics were obtained in time intervals of 30 to 60 min. and at acid levels of 6 and 8% based on the chips. The high alpha-cellulose content of pulp no. 24 suggests that the conditions under which it was prepared were near optimal with regard to product purity. Comparison of pulp no. 26 from hydrolysis at 150°C. with a similar pulp (no. 25) from hydrolysis at 140°C. indicates that, as desired by the operator, flexibility of operating conditions can be achieved to give the same result by using longer times at low temperatures or the reverse.

*Hydrolyses by Water and Steam.* A limited number of experiments were performed using water or steam as the hydrolytic agent (Table III). Under the same conditions of operation (pulp no. 16 vs. 19) equivalent results were obtained with the exception that ash removal was less complete with steam. At equivalent levels of pentosan removal both water and steam appeared to promote somewhat greater depolymerization of cellulose than did the nitric acid. Likewise, there was a trend toward lower yields than when mineral acid was employed. These factors need to be considered when weighing the relative economy of water or steam against the added beneficial effects of mineral acid.

*Milling after Hydrolyses.* Initially, acid removal from chips following nitric acid hydrolyses was accomplished by a steeping-filtration technique performed until the wash liquor was substantially free from color and essentially neutral in pH value. Pulps for the first group of experiments in Table III were freed from nitric acid in this manner. However, prolonged steeping in wash water extracted further quantities of acid that remained in the interior of the chips and was not removed initially. This residual acid could contribute to the variability among runs by partially neutralizing alkaline pulping liquors, or by causing a small amount of further chemical action if washed, hydrolyzed chips were allowed to stand before further processing. Consequently, the more thorough washing procedure using the disk mill was adopted, as described in the experimental section, and this procedure was used for the second group of pulps in Table III.

Actually, experimentally determined characteristics of the pulps do not seem to be greatly influenced by the use or omission of this milling step during washing. Alpha-cellulose and pentosan values are in close agreement whether hydrolyzed chips were milled or not. Differences observed in brightness, degree of polymerization, and also yield indicate no significant effect attributable to the milling procedure.

*Comparison of Experimental and Commercial Pulps.* Comparison of the properties of selected experimental bamboo pulps with eight samples representing three grades of commercial, wood-derived dissolving pulps prepared by a similar process is shown in Table IV. Bamboo pulps readily meet or exceed commercial requirements for cellulose, pentosans, brightness, ash, and ether-soluble substances. The somewhat higher disperse viscosities of the experimental pulps, indicative of lesser degradation of the cellulose chains, can undoubtedly be brought to any desired level by controlled acidic processing to effect slight additional hydrolysis.

The characteristics indicated by our investigations constitute only a preliminary evaluation of bamboo as a raw material for dissolving pulp. Actual performance tests to indicate chemical reactivity in viscose formation, behavior toward aging, viscosity, filterability and spinnability of the xanthation mixture, and strength properties of the finished film or fibers need to be studied in a complete appraisal. Developmental studies may even necessitate some processing changes over those recommended on the basis of our preliminary work. However, present results are certainly encouraging in indicating the potential of domestically grown *P. bambusoides* for the production of high-grade chemical cellulose.

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# The Effect of the Hypochlorite Bleaching Variables on Prehydrolyzed Sulfate Hardwood Pulp Properties

J. W. SMITH and W. L. THORNBURG

**The effects of five hypochlorite bleaching variables on the chemical properties of prehydrolyzed sulfate hardwood pulps were investigated by means of a five-factor orthogonal second order composite design. The single replicate of 27 experiments, sufficient to detect linear effects of the magnitude of one standard deviation, was made to determine the influence of temperature, time, per cent available chlorine, starting pH and incoming viscosity in the hypochlorite bleaching stage on the resulting pulp viscosity, Swedish solubilities and steeped pulp color. Data, collected for each experiment following the hypochlorite stage and also for the finished pulp, were statistically evaluated. The results of the statistical evaluation of the data for the various pulp properties are presented in the form of mathematical equations. Examination of values obtained from the calculation of the various equations permits the following observations: (1) Starting pH is by far the most important variable in the hypochlorite bleaching stage, since it is the only variable affecting every pulp property at the 99% confidence level; (2) Temperature and per cent available chlorine appear to be nearly equal in their effect on the various pulp properties; (3) Time has considerably less effect than do any of the three variables above, with the incoming viscosity having the least effect; and (4) The Swedish solubilities of the unbleached pulp appear to pass through a maximum when approximately 19.5% active alkali is used in the sulfate cook, and these solubilities do not appear to change greatly during the subsequent bleaching treatments.**

In most bleaching sequences for paper grade pulps, the hypochlorite treatment is used primarily to control the brightness; while in sequences for dissolving grade pulps, this stage is used to control viscosity.

Our problem was to determine the influence of temperature, time, per cent available chlorine, starting pH and incoming viscosity in the hypochlorite bleaching stage on the resulting pulp viscosity and other properties. The effects of these five hypochlorite bleaching variables on the chemical properties of prehydrolyzed sulfate hardwood pulps were investigated by means of a five-factor orthogonal second order composite design.

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## MATERIALS

The materials employed in this study consisted of:

1. Five laboratory prepared southern hardwood prehydrolyzed sulfate pulps. These pulps were given a chlorination and a hot caustic extraction, placed in polyethylene bags and stored in the dark at about 80°F. until they were required for the bleaching study. A chlorine addition of [(0.3) (TAPPI permanganate number)] was used for the chlorination treatment.

2. The hypochlorite bleach liquor was prepared by bubbling commercial chlorine gas into a solution of 24% c.p. sodium hydroxide. The available chlorine concentration was approximately 22 g p l.

## EXPERIMENTAL

A second order composite design in five variables was proposed. A single replicate of 27 experiments is sufficient to detect linear effects of the magnitude of one standard deviation.

Table I shows the levels of the variables, the factor codes, and gives the range of the variables used in this experiment. Thus we see that temperature ranged from 34.5 to 65.5°C., time was varied from 0.45 to 3.55 hr., per cent available chlorine was varied from 0.73 to 2.27%, starting pH was varied from 9.0 to 12.0 and the incoming viscosity was varied from 5.6 to 30.4 cp. The nonintegral values for the $\alpha$ points should not

**Table I. Levels of Factors**

| Factor code | Level $-\alpha$ | $-1$ | 0 | $+1$ | $+\alpha$ |
|---|---|---|---|---|---|
| A—temperature, °C. | 34.53 | 40 | 50 | 60 | 65.47 |
| B—time, hr. | 0.453 | 1 | 2 | 3 | 3.547 |
| C—available chlorine, % | 0.7265 | 1 | 1.5 | 2 | 2.2735 |
| D—starting pH | 8.953 | 9.5 | 10.5 | 11.5 | 12.047 |
| E—incoming viscosity, CED 0.5%, cp. | 5.624 | 10 | 18 | 26 | 30.376 |

give rise to any difficulty in practice. To the extent that it is possible to control a variable, for example pH at 10.5, it should be possible to control it at 8.9.

The pulp viscosity was determined using the 0.5% cupriethylendiamine (CED) TAPPI Standard T 230 sm-50. The caustic solubilities were determined using the Swedish Standard CCA 8:55. The steeped pulp color values were obtained using a tristimulus Colormaster colorimeter.

Twenty-seven experimental runs were made according to the conditions listed in Table II, but in random order. Data were collected for each run after the hypochlorite stage and for the finished pulp properties. Following the hypochlorite stage, each pulp was further purified by an acidified chlorite bleach procedure.

## RESULTS AND DISCUSSION

The results of the statistical evaluation of the data obtained for the various pulp properties will be presented in the form of mathematical equations. It should be pointed out that only those variables having an effect at the 99% confidence level or greater will be presented in this paper. It is recognized that some degree of bias is introduced by presenting only data at the 99% level; however, it was felt that this is necessary for the sake of simplicity.

The first results presented are those for the CED viscosity and the Swedish solubilities S-10 and S-21.5 obtained for the various pulps immediately after the hypochlorite treatment.

$$\text{CED viscosity} = -2.0206A - 1.2845B - 1.4336C + 1.4577D + 1.4000E + 1.0125AB + 7.05 \quad (1)$$

Equation (1) shows the effects of the variables on CED viscosity. The equation is written in terms of the coded levels of Table I. Consider temperature ($A$) and its effect on viscosity. With the substitution of the coded values for the temperature level, as selected from Fig. 1, the effect of temperature on the CED viscosity may readily be calculated. Any combination of levels of the other variables may be chosen by proper selection of their coded values from Fig. 1.

The regression coefficients show that the CED viscosity decreases linearly as temperature is increased. This same observation is also true for per cent available chlorine ($C$) and time ($B$). However, considering starting pH ($D$) and incoming viscosity ($E$), it will be noted that as either pH or viscosity is increased the viscosity after the hypochlorite stage increases.

Thus an increase in temperature, time and/or per cent available chlorine will result in a decrease in viscosity while an increase in starting pH and/or viscosity increases the viscosity after the hypochlorite stage.

$$\text{S-10\%} = 2.1600A + 2.3188C - 3.0789D + 8.28 \quad (2)$$

Equation (2) illustrates the effect of temperature ($A$), per cent available chlorine ($C$), and pH ($D$) on the S-10 solubility. This equation shows that the S-10 solubilities are increased as temperature and/or per cent available chlorine are increased, and that the S-10 solubility values decrease as the pH is increased.

**Table II. Experimental Design**

| Run no. | Coded variable A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | 40 | 1.0 | 1.0 | 9.5 | 10 |
| 2 | 60 | 1.0 | 1.0 | 9.5 | 26 |
| 3 | 40 | 3.0 | 1.0 | 9.5 | 26 |
| 4 | 60 | 3.0 | 1.0 | 9.5 | 10 |
| 5 | 40 | 1.0 | 2.0 | 9.5 | 26 |
| 6 | 60 | 1.0 | 2.0 | 9.5 | 10 |
| 7 | 40 | 3.0 | 2.0 | 9.5 | 10 |
| 8 | 60 | 3.0 | 2.0 | 9.5 | 26 |
| 9 | 40 | 1.0 | 1.0 | 11.5 | 26 |
| 10 | 60 | 1.0 | 1.0 | 11.5 | 10 |
| 11 | 40 | 3.0 | 1.0 | 11.5 | 10 |
| 12 | 60 | 3.0 | 1.0 | 11.5 | 26 |
| 13 | 40 | 1.0 | 2.0 | 11.5 | 10 |
| 14 | 60 | 1.0 | 2.0 | 11.5 | 26 |
| 15 | 40 | 3.0 | 2.0 | 11.5 | 26 |
| 16 | 60 | 3.0 | 2.0 | 11.5 | 10 |
| 17 | 50 | 2.0 | 1.5 | 10.5 | 18 |
| 18 | 34.53 | 2.0 | 1.5 | 10.5 | 18 |
| 19 | 65.47 | 2.0 | 1.5 | 10.5 | 18 |
| 20 | 50 | 0.453 | 1.5 | 10.5 | 18 |
| 21 | 50 | 3.547 | 1.5 | 10.5 | 18 |
| 22 | 50 | 2.0 | 0.7265 | 10.5 | 18 |
| 23 | 50 | 2.0 | 2.2735 | 10.5 | 18 |
| 24 | 50 | 2.0 | 1.5 | 8.953 | 18 |
| 25 | 50 | 2.0 | 1.5 | 12.047 | 18 |
| 26 | 50 | 2.0 | 1.5 | 10.5 | 5.624 |
| 27 | 50 | 2.0 | 1.5 | 10.5 | 30.376 |

$$\text{S-21.5\%} = 0.4907A + 0.5532C - 0.8275D - 0.7509E^2 + 4.388 \quad (3)$$

Equation (3) shows the effects of the hypochlorite bleaching variables on the Swedish solubility, S-21.5. Just as was the case with the per cent S-10, the S-21.5 solubility values increase as the temperature and/or per cent available chlorine is increased and decrease as the pH is increased. We have, however, a notable exception occurring with the S-21.5 solubility that did not occur in the case of the S-10 solubility, and that is the incoming viscosity has a quadratic relationship with the S-21.5 solubility. It will be noted that the values of the S-21.5 solubility reach a maximum at the 0 coded level of viscosity and then decrease with either an increase or decrease in viscosity from that level. Further

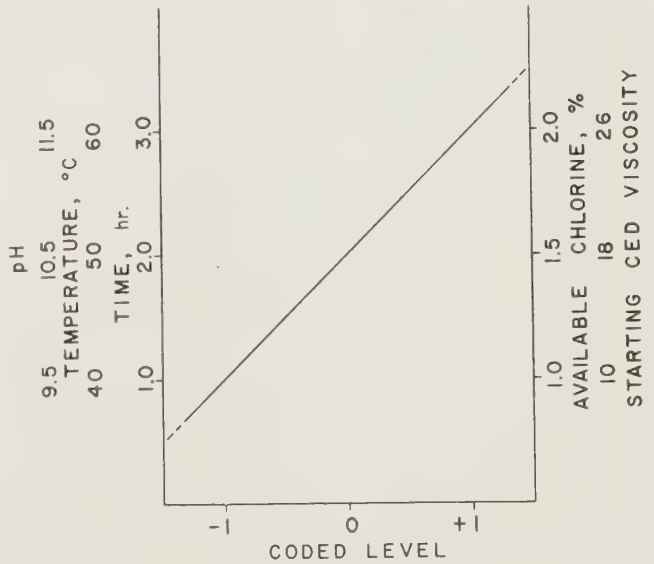


***Fig. 1. Coding chart***
For example, 60°C. = +1.

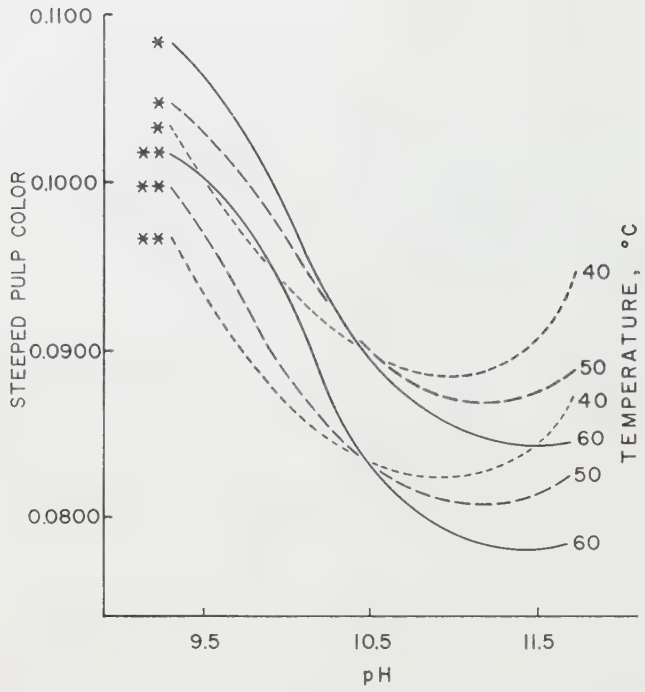


*Fig. 2.*

* Incoming viscosity = 18 cp. ** Incoming viscosity = 10 or 26 cp.

observations on this relationship will be presented later in this paper.

Visual examination of the equations depicting the effects of the hypochlorite bleaching variables on the pulp properties after the hypochlorite stage shows that pH, per cent available chlorine, and temperature are extremely important in hypochlorite bleaching. These equations indicate the following order of importance for the five variables: (1) starting pH, (2) per cent available chlorine, (3) temperature, (4) time, and (5) incoming viscosity.

The preceding equations have dealt with the effects of the hypochlorite bleaching variables on properties of pulps immediately after the hypochlorite stage. The next group of equations will show the effects of these variables on the finished pulp properties: CED viscosity and Swedish solubilities S-10 and S-21.5. In addition to these equations, one graph, Fig. 2, will be presented depicting the relationship of the significant variables to the steeped pulp color. Here again, only those variables affecting the pulp properties at a significance level of 99 per cent or greater will be reported.

$$\text{CED viscosity} = -1.1594A - 0.7264B - 1.0247C + 1.2075D + 0.8371E + 5.41 \quad (4)$$

Equation (4) depicts the effects of the five variables on the finished pulp CED viscosity. As in the case of viscosity after the hypochlorite stage, the final viscosity decreases as temperature, time, and/or per cent available chlorine is increased and increases as pH and/or incoming viscosity increases. Observing the coefficients of the five variables, it will be noted that the effects of time and incoming viscosity are considerably less than those of the other three.

It may be noted that in the case of the final viscosity there is no temperature-time interaction as was noted for the viscosities after the hypochlorite stage. However, this interaction was observed at the 95% confidence level. It is believed that this interaction effect is leveled out by subsequent purification, thus is not observed at the 99% level.

$$\text{S-10\%} = 2.5113A + 2.7759C - 3.7476D - 1.9436E + 9.504 \quad (5)$$

Equation (5) shows the effects of temperature, per cent available chlorine, starting pH, and incoming viscosity on the per cent S-10 Swedish solubilities. As temperature and/or per cent available chlorine are increased, the S-10 values increase while an increase in pH and/or incoming viscosity results in a decrease of the S-10 values. A comparison of this equation with that for S-10 after the hypochlorite stage indicates that the coefficients for the various variables are of the same order of magnitude for both equations. Thus the S-10 values calculated by either equation will not differ greatly. Examination of the coefficients, again indicates that pH is the more important variable in the control of the S-10 value.

The effect of incoming viscosity on this finished pulp property was not observed in the equation for the S-10 values after the hypochlorite stage. However, the same effect is observed for the S-10 equation after the hypochlorite stage at the 95% level. A possible explanation for our failure to observe this effect at the 99% level is that the error term is somewhat larger for the equation at the end of the hypochlorite stage. Thus the evaluation did not pick up this effect.

$$\text{S-21.5\%} = -0.6831\ \text{D} + 3.70 \quad (6)$$

Equation (6) indicates the effect of pH on the S-21.5 solubility. The S-21.5 values decrease as the starting pH is increased. In a comparison of this equation with the one for S-21.5 following the hypochlorite stage, it will be noticed that temperature, per cent available chlorine and incoming viscosity do not appear in the equation for the final pulp. However, at the 95% confidence level these three terms were observed. In this case, the error terms for both equations were almost identical. Thus it is concluded that during the subsequent acid chlorite purification the effect of temperature, per cent available chlorine and incoming viscosity are leveled out enough so that they are not observed at the 99% level.

Further verification of the fact that the effects of these three variables are leveled out in the chlorite purification step may be obtained by observation of the calculated values for these equations. Such an observation indicates that the values at the end of the hypochlorite stage are larger than those for the finished pulp property.

The last property to be discussed in this presentation is that of steeped pulp color. The results for this finished pulp property will be presented in the form of a graph. Calculation of the following equation for this property permits the plotting of the family of curves shown in Fig. 2, where pH is plotted on the $X$-axis and steeped pulp color on the $Y$-axis.

$$\text{Steeped pulp color} = -0.0077D - 0.0032AD + 0.0059D^2 - 0.0062E^2 + 0.0893 \quad (7)$$

The following significant responses were noted for this property: (1) a linear response with pH; →, (2) a temperature-pH interaction, and (3) quadratic responses for pH and incoming viscosity.

**Table III. Confirmation Results for Pulp Properties After the Hypochlorite Treatment**

| Pulp | CED Viscosity, Predicted | CED Viscosity, Observed | S-10, % Predicted | S-10, % Observed | S-21.5, % Predicted | S-21.5, % Observed |
|---|---|---|---|---|---|---|
| | 6.2 | 6.0 | 9.7 | 7.4 | 3.8 | 3.5 |
| | 6.2 | 6.5 | 9.7 | 7.6 | 3.8 | 3.4 |
| | 6.2 | 6.0 | 9.7 | 7.8 | 3.8 | 3.5 |
| Error term | 0.64 | | 2.71 | | 0.67 | |

The following conclusions appear to be valid for this pulp property:

1. Steeped pulp color reaches a maximum in the range of an 18 cp. incoming viscosity and then decreases as the viscosity is either raised or lowered from this point.

2. At any given incoming viscosity the steeped pulp color decreases as the temperature is increased using a pH greater than 10.5, but at pH values less than 10.5, color increases as the temperature is increased.

3. Steeped pulp color appears to be independent of temperature for any given incoming viscosity when a pH value of 10.5 is used.

4. A high temperature-high pH favors lower steeped pulp color.

As in the case of the pulp properties after the hypochlorite stage, starting pH is also the most important variable with respect to the finished pulp properties. A comparison of the coefficients of the starting pH for the two sets of equations indicates that pH has a somewhat stronger effect in the case of the pulp properties at the end of the hypochlorite stage than it does for the finished pulp properties. pH is the only variable affecting all properties at the 99% level of significance. Other variables fall into the following order of importance: temperature; per cent available chlorine; incoming viscosity; and time. This order is based on the number of equations in which the variable appears and the magnitude of the regression coefficients.

**Table IV. Effect of Per Cent Active Alkali and Bleaching Sequence on S-21.5, Per Cent**

| AA, % | S-21.5, % Unbleached pulp | S-21.5, % Before hypo stage | S-21.5, % After hypo stage | S-21.5, % Finished pulp |
|---|---|---|---|---|
| 22.6 | 2.5 | 2.3 | 2.7 | 2.8 |
| 21.5 | 3.0 | 2.5 | 3.8 | 3.8 |
| 19.5 | 4.0 | 3.4 | 4.5 | 4.3 |
| 17.5 | 3.3 | 2.4 | 3.3 | 3.1 |
| 16.4 | 3.2 | 2.8 | 3.2 | 3.1 |

Brightnesses after the hypochlorite stage and for the finished pulp were not significantly affected by any of the hypochlorite variables. This could be the result of the extent of the hypochlorite bleaching since all pulps were bleached to relatively low viscosities. In this viscosity range, the brightness appears to be relatively insensitive to changes in the treatment conditions.

A series of confirmation bleaches were made, using values for the hypochlorite bleaching variables as predicted by the various equations presented here, to obtain predetermined properties at the end of the hypochlorite stage and for the finished pulp. Table III shows a comparison of predicted values with the observed values when only temperature was varied to bleach three pulps with incoming viscosities of 26, 20, and 17 cp. The values shown are those for viscosity, S-10 and S-21.5 solubilities at the end of the hypochlorite stage. Similar data have been obtained for bleaches where pH, time and per cent available chlorine were varied independently. Analytical data were also obtained for the finished pulp properties of each sample. Except for a few cases, the predicted values and the observed values did not differ in magnitude greater than that of the standard error term of the experiment. However, in the case of the S-10 solubilities, the observed values were consistently lower than the predicted values.

To further substantiate the applicability of the statistical calculation, a single pulp with a viscosity of 15.8 cp. was bleached to the same final viscosity by using different combinations of levels of the variables. Again, the differences between the predicted and observed values were not greater than the standard error term.

To obtain the five levels of incoming viscosity used in this study, pulps were prepared varying only the per cent active alkali in the sulfate cook. The per cent active alklai varied from 16.4 to 22.6% with all other pulping conditions being held constant. Data for the various pulp properties were collected for the unbleached pulp, before and after the hypochlorite stage and for the finished pulp. These data, tabulated in order of increasing per cent active alkali (see Table IV for the per cent S-21.5 solubility data) allow the following observations:

1. The Swedish solubility, S-21.5, does not appear to change significantly during the bleaching purification procedure. However, this value shows a slight decrease through the extraction stage, with a small increase during hypochlorite bleaching.

2. A second observation noted here is that the Swedish solubilities reach a maximum value in the vicinity of 19.5% active alkali. A possible explanation would be that with increasing alkali levels, the solubilities increase to a point where the residual alkali tends to extract a portion of the degradation products.

3. A third observation is that the S-10 solubility follows the same pattern as does S-21.5, but appears to increase considerably more during the hypochlorite bleaching stage.

We have verified these three observations repeatedly and they were found to be true in every case.

## CONCLUSIONS

In summary we make the following conclusions based on the data obtained from this investigation:

1. Starting pH is by far the most important variable in the hypochlorite bleaching stage, since it is the only variable affecting every pulp property at the 99% confidence level. With only one exception, pH had the highest regression coefficient of any of the variables affecting any pulp property.

2. Temperature and per cent available chlorine appear to be nearly equal in their effect on the various pulp properties.

3. Time has considerably less effect than do any of the three variables above, with the incoming viscosity having the least effect of all.

4. The Swedish solubilities of the unbleached pulp appear to reach a maximum when 19.5% active alkali is used in the cook and do not appear to change greatly during the bleaching sequence.

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# The Relation of Fiber and Pulp Properties to the Properties of Structural Fiberboard Products

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**In recent years a number of laboratories throughout the world have been engaged in determining the relationship between basic properties of cellulose fibers and pulp suspensions and the characteristics of paper made from such fiber. The objective has been to expand our understanding and control of these relationships beyond that obtainable through laboratory small-scale simulation of commercial production. When we extend this type of analysis to insulation board and hardboard, we must deal with the much greater chemical and physical complexities of the fibrous raw materials. A review is presented of the recently published work on pulp evaluation, including that on fiber strength, fiber flexibility, drainage resistance, surface area, swollen volume, and bonding strength. The extent to which these tools may be applicable to structural fibrous materials is considered and possible modification of present techniques for such purpose are suggested.**

THE problem of characterizing a sample of wet fiber pulp so that the properties of paper or board made from that pulp can be accurately predicted is complex and difficult. Many interrelated factors are involved, such as the chemical composition of the fiber, fiber dimensions, fiber strength, surface area and unit bonding strength, fiber flexibility, flocculation characteristics, and filtration resistance of the fiber-water system. The problem is formidable enough for fine papers made from a single long-fibered bleached pulp. It is much more difficult for the structural fiberboard products in which we are now interested.

The traditional approach to this situation has been to attempt to simulate in the laboratory the refining, forming, and drying steps of the manufacturing operation. While this procedure may tell whether a given pulp so processed will be good or poor for a given product, it obviously does not get at the question of why the pulp behaves as it does. We touch on this with a few empirical tests such as freeness and fiber classification but gain very little basic information thereby.

In recent years, a number of laboratories throughout the world have been working in this area and have made important advances. It is natural and proper that this pioneering work has been designed and carried out with the simplest possible cases of fiber-to-paper property relationships. Some of the things that have been accomplished and how these results might be applied in the structural fiberboard area will be reviewed.

Instruments and techniques have been developed for measuring the tensile strength and elongation characteristics of individual wood fibers (*1–3*). These developments are relatively recent, and major applications still lie ahead. Possibly, the most valuable use to date has been the establishment of the validity of the zero-span tensile test for the measurement of fiber strength.

The zero-span tensile test, as the name implies, involves tensile rupture of a sheet of paper with the jaws so close together that the individual fibers are firmly gripped and ruptured. Van den Akker and co-workers (*3*) showed by mathematical analysis of fiber orientation factors that the zero-span test should yield a breaking stress equal to $^3/_8$ of the tensile breaking stress of the same fibers tested individually. Experimental evaluation of this relationship yielded very good agreement and provides justification for interpreting zero-span tensile values in terms of individual fiber strength.

In the past there has been much confusion and uncertainty concerning the importance of the strength of the individual fiber in determining the strength of a sheet of paper. The majority opinion was that very few fibers failed in rupturing paper and that the strength of the paper was determined predominantly by the fiber-to-fiber bond. This has been tested experimentally and it has been found that a much higher proportion of fibers fail than was generally realized (*3*).

The extent of fiber failure in paper failure during tearing and tensile rupture was studied by microscopic examination of paper before and after rupture. By the use of dye tagged fibers distributed through the sheet, substantial percentages of the fibers involved in the zone of rupture were observed to fail—of the order of 60 to 70%, even when the degree of beating was moderate. In the case of tensile failure, it was possible to study the prevalence of fiber failure as a function of degree of beating, degree of bonding, fiber length, and fiber orientation. In this work, for the first time, it was clearly shown that fibers fail when paper fails and that the proportion of fibers failing to fibers pulling apart was higher than generally previously estimated. This has significantly influenced subsequent work, in that more importance has been placed on individual fiber strength.

It is not known whether there is any published work on the significance of individual fiber strength to the properties of structural fiberboard. From what has been learned in the case of paper, the prediction might be made that, for average strength pulps, individual fiber strength has little influence on strength properties of board products in the specific gravity range of 0.25 to 0.40; that it becomes significant in the range 0.40 to 0.70; and that it may be the predominant factor for hardboard of 0.90 and higher specific gravity.

It certainly seems to be worth while to develop this application to structural fiberboard, even though there will be experimental difficulties to overcome. The zero-span tensile test is known to be questionable for sheets more than a few thousandths of an inch thick.

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In order to be able to form suitable thin sheets from structural fiberboard pulps, it would probably be necessary to fractionally classify the pulp, run zero-span tensile only on the most uniform long-fibered fractions, and take the classification data into account in interpreting the results obtained. There is no apparent reason why individual fibers could not be separated from such pulps for direct fiber tensile tests. The problem here would be to determine whether such sampling gave results significant with respect to the whole pulp.

If such techniques for the determination of fiber strength could be established, it would then be possible to evaluate such variables as wood species, pulping condition, and drying treatments on fiber strength and to explore the relationship of this fiber property to board properties.

Continuing with our consideration of fiber properties, a great deal of attention has naturally been given to the important question of fiber-to-fiber bonding. Attack on this complex problem has necessarily required subdivision into components. One of these factors is the extent of fiber surface area available for bonding.

There are many surfaces to be considered with respect to a fiber. There is the external surface of the primary wall and distended fragments, the surface of the pits and lumen, and the surface of fibrils making up the fiber. Through the years a number of methods have been developed for surface area measurement. These include: (a) the geometric method of direct microscopic measurement; (b) the silvering technique, based on decomposition of hydrogen peroxide catalyzed by a thin layer of silver deposited on the fibers; (c) dye adsorption; (d) gas adsorption, involving the surface adsorption of gases such as nitrogen and krypton at low temperatures; and (e) filtration resistance, which provides a measure of the hydrodynamic external surface. It is not possible here to go into the details of these various methods. The point to be emphasized is that each of these methods measures a different surface, and the particular problem to be solved should determine the method selected for application.

In the case of paper-grade bleached pulps free of fines, relatively good agreement for external area of wet pulps in the range of 5000 to 20,000 sq. cm. per g. are obtained by the geometric, silvering, dye adsorption, and filtration resistance methods. The same pulps, solvent dried and unbonded, will yield total surface areas by the gas adsorption technique of the order of several million sq. cm. per g.

When we consider structural fiberboard pulps, our choice of methods for surface area determination is sharply limited. The high proportion of fiber bundles and fiber debris makes the geometric method unsatisfactory, and the high noncellulose and fines contents render the silvering and dye adsorption techniques unreliable. The most promising methods presently available in this situation are the filtration resistance method for external surface and the gas adsorption technique for total area. We will return to the subject of filtration resistance shortly. At this point in our consideration of fiber-to-fiber bonding in structural fiberboard products, we are dependent upon this technique for the measurement of area available for bonding. We need now some way of measuring bonded area and bond strength to complete the analysis.

For the relatively simple bleached paper-grade pulps, optical-scattering measurements have proved quite useful as an indirect tool for measuring relative bonded area (*4–6*). It would be expected that this technique would be unsuitable for the majority of structural fiberboard products because of the high level of light absorption and high proportion of coarse fiber bundles. The only method immediately apparent that might be applicable would be the measurement of gas adsorption surface areas for sets of boards pressed to different densities from the same wet-laps.

The measurement of fiber-to-fiber bonding strength is not well developed even for the simplest paper situation. Some use is being made of the oil-stripping test for paper in this area, as in the I.P.C. bonding strength test (*7–9*) but there is no apparent basis for applying a similar test method to structural fiberboard. It is possible that a simple transverse, or z-direction, tensile test might at least partially satisfy the need for board applications.

From the elements of fiber-to-fiber bonding that we have considered, it is evident that the objective sought is to be able to characterize a given pulp with respect to inherent bonding strength per unit of surface, external area available for bonding, and proportion of this area that is bonded. Such knowledge would put us on a different level of process design and control of boardmaking operations.

Of all the tools for pulp evaluation that we are considering, filtration resistance measurement is undoubtedly the most directly applicable to structural fiberboard problems. For this reason it deserves special attention.

The freeness test is, of course, related to filtration resistance, but its significance is severely limited by the arbitrary establishment of conditions and lack of control of important variables. By getting at the fundamental variables and establishing the necessary controls, it has been possible to create an extremely valuable method of pulp analysis. Robertson and Mason (*10*) at the Pulp and Paper Research Institute of Canada have developed a method based on measurement of water flow through uniformly compacted fiber mats. They and their students have reported a number of studies of pulp evaluation using this technique. Concurrently, Ingmanson (*11*) and co-workers at The Institute of Paper Chemistry have developed a method based on measurement of resistance to flow of a pulp pad as it is being formed from a dilute slurry, the measurement being made either at constant rate of flow or constant pressure conditions.

Filtration resistance determinations are of direct value in process design and control problems. Two recent articles (*12, 13*), have shown that filtration resistance can be used to quantitatively predict drainage during commercial sheet-forming operations. Such applications are being made in equipment design situations as well as optimization of operating conditions for existing machines. In addition to the direct determination of drainage rate, filtration resistance data yield values for surface area and swollen specific volume of the pulp. We have already discussed the importance of surface area and will return to the subject of swollen

volume. These determinations are of great value in evaluation of pulping and refining operations, both from design and control viewpoints.

The filtration resistance technique is particularly attractive for structural fiberboard pulps because of the lack of sensitivity of a freeness test in the high freeness range. For example, the initial refining treatment of a paper pulp which produced a change of only from 775 to 700 ml. Canadian Standard freeness represented a threefold change in specific filtration resistance.

The measurement of swollen specific volume that is secured from the filtration resistance determination is worthy of attention. For paper, values for swollen volume have been found to correlate well with a number of strength properties. It is believed that this correlation derives from the close relationship of swollen volume to fiber flexibility. Certainly, fiber flexibility is important in structural fiberboard operations, through its influence on wet-pressing response, shrinkage behavior, and product strength. More direct methods for measuring fiber flexibility are needed, and several laboratories are currently working on this problem.

This has been a brief outline of the current status of development of fiber-evaluation techniques in the area of physical properties. Time does not permit consideration of the much more complex subject of chemical characteristics. An effort has been made to evaluate the applicability of the tools considered to structural fiberboard pulps. It is hoped that it has been made clear that few of these techniques can presently be applied to these pulps without modifications, but that research work leading to such applications would be well justified.

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# Adsorption Sampling and Gas Chromatographic Analysis of Sulfur Compounds in Waste Process Gases


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**A new procedure for source sampling and analysis of malodorous, sulfur-containing gases from the kraft pulping process has been developed. The pollutants are adsorbed and/or are condensed on activated silica gel at −78.5°C., desorbed under conditions of heat and vacuum, trapped at −195.8°C., and transferred onto a gas-liquid chromatographic column for analysis in a conventional manner using a rising column temperature technique. Water vapor, being more polar thanthe malodorous vapors, must be preferentially removed from the source sample prior to adsorption to prevent chromatographic elution of less polar compounds. The major portion of the water is eliminated by condensation at 0°C. and additional water vapor is subsequentially removed on a solid desiccant such as anhydrous calcium sulfate.**


Considerable money and effort have been expended by the kraft pulp industry for the development and installation of process equipment to reduce atmospheric losses of malodorous sulfur compounds. Proper evaluation of the effectiveness of the various control methods, as well as justification of further capital expenditure for installation of additional control equipment, is obviously dependent upon the availability of rapid, adequate, and practical sampling and analytical techniques.

Numerous researchers have proposed procedures for conventional collection and chemical analysis of these collected malodors (*5, 9, 13, 14, 31*). However, none of the presently available methods are suitable for rapid control analysis, since they involve complex laboratory manipulations and many man-hours to complete the analysis of a single sample. Therefore, many mills have not attempted an evaluation of their control equipment.

The problem of determining the identity and quantity of pollutants in stack gases resolves itself into two major steps: sampling and analysis. This present paper describes (a) a method for the collection of kraft mill waste gases in a manner suitable for gas-liquid chromatographic analysis, and (b) two alternative procedures for gas chromatographic analysis of the collected sample.


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## DISCUSSION

### *Sampling*

Three sources of potential interference must be overcome in the collection of stack samples for gas chromatographic (GLC) analysis: water, carbon dioxide, and air. Each may be present in quantities many times greater than the malodors to be measured in the recovery furnace stack, digester relief and blow, lime kiln, and evaporator noncondensable gases. Should any of these interfering substances be present in the sample, broad response peaks may appear which will virtually mask those of the malodorous pollutants. Further-

**Table I. Dipole Moments and Boiling Points**

| Compound | Dipole moment, Debye units[a] | Boiling point, °C. |
|---|---|---|
| Water | 0.74–1.97 | 100.0 |
| Sulfur dioxide | 1.61–1.83 | −10 |
| Ethyl sulfide | 1.51–1.61 | 92 |
| Ethyl mercaptan | 1.39–1.56 | 36 |
| Methyl mercaptan | ... | 5.8 |
| Methyl sulfide | 1.40 | 38 |
| n-Butyl mercaptan | 1.32–1.49 | 88 |
| Hydrogen sulfide | 0.89–1.17 | −59.6 |
| Chlorine dioxide | 0.78 | 9.9 |
| Nitrogen tetroxide | 0.00–0.58 | 21.3 |
| Nitrogen dioxide | 0.29–0.33 | −151 |
| Chlorine | 0.23 | −34.6 |
| Carbon disulfide | 0.00–0.49 | 46.3 |
| Carbon dioxide | 0.00–0.30 | 78.5 |
| Carbon monoxide | 0.10–0.13 | −192 |
| Nitrous oxide | 0.00–0.25 | −89.5 |

[a] Debye unit = $1 \times 10^{-18}$ esu units.

more, because of the limited sample volume used in GLC analysis, the presence of large percentages of water, carbon dioxide, and air in a sample would effectively limit the proportion of pollutants present in a given sample volume.

Thus the development of a sampling method must solve the basic problems of separation of water, carbon dioxide, and air from the sulfur compounds. In addition, the method should not result in a dilution of these gases in a carrier or absorbing media.

Air pollutants have been collected for chromatographic and spectrographic analysis by freezing-out in a cold trap (*4, 17, 20, 28*) or by adsorbing them on activated surfaces followed by desorption into the mass spectrograph or gas chromatograph (*30*). Although the problems of concomitant water, carbon dioxide, and air are present when sampling ambient air, the concentrations of the water and $CO_2$ are of a much lower magnitude than in pulp mill waste streams. Thus these procedures are not directly applicable to the stack sampling problem.

While the adsorption sampling technique herein reported was being developed, Cave reported an absorption sampling technique developed specifically for pulp mill effluent gases (*7*). Ethyl benzene was used as the absorption liquid. Samples thus obtained are suitable for subsequent GLC analysis, however, the method involves several analytical complexities. One or two complex fractional distillations are required to concentrate the collected malodors in 3 to 8 ml. of the 30 to 50 ml. of ethyl benzene used to scrub the stack gases. Even following fractionation, the malodors represent a minor portion of the sample liquid to be chromatographed. Although the ratio of ethyl benzene to malodors is considerably improved by the fractionation, the presence of relatively large concentrations of the ethyl benzene solvent loads the GLC column with extraneous response-masking material. This places a limit on the number of samples which can be consecutively chromatographed before the column must be purged of accumulated ethyl benzene.

In view of the difficulties inherently associated with freeze-out and absorption sampling, the use of adsorption sampling appeared to satisfy a greater number of requirements for an ideal GLC sample and was therefore chosen for study.

Initial study of the adsorption of $H_2S$, $CH_3SH$, and $SO_2$ on activated charcoal showed that they could neither be desorbed at 200°C., nor under combined conditions of heat and vacuum. It is quite likely that these sulfur compounds are catalytically converted to elemental sulfur on the carbon surface, thus preventing desorption (*26*).

Adsorption of the malodors on activated silica gel was next considered, since the literature indicated that silica gel is a good adsorbant for polar compounds (*6*). From the wide range of boiling points and dipolar moments of the malodorous compounds present in the various emissions (see, Table I) (*29*), and from their adsorption isotherms at various temperatures, it was realized that the silica gel should be cooled near or below the boiling points of the compounds of interest to realize maximum collection efficiency. The minimum temperature of the adsorbant was limited to −78.5°C., because of the relatively large quantity of $CO_2$ anticipated. Obviously, lower adsorption temperatures would result in rapid plugging of the adsorption tube with solid $CO_2$. Similarly, water must be removed from the sampled gas prior to adsorption if the adsorption column were to be maintained below 0°C. Furthermore, water (having a high dipole moment) if present, would elute adsorbed compounds having a lower dipole moment.

These were the problems which had to be considered and solved in the development of a suitable adsorption sampling method.

### *Analysis*

Gas chromatography has recently been used to study sulfur compounds. Numerous investigators (*3, 7, 8, 15, 16, 19, 21, 23, 24*) have successfully separated various mixtures of sulfur-containing compounds on a wide variety of liquid solvents such as TCP, β,β′-iminodipropionitrile, squalene, dinonyl phthlate and 550 silicone oil. Several of these authors utilized the two-temperature technique of Drew, *et al.* (*10*), or nonlinear temperature programming (*23*), to reduce the elution time for the higher boiling components of their mixtures.

Adams and Koppe (*1, 2*) have recently published two reports on the separation of 16 sulfur-containing malodors using a series of alkyl aryl polyether alcohols (Rohm and Haas Triton series nonionic surface-active agents) as column solvents. By utilization of the variations in properties of these solvents, and a nonlinear rising temperature technique, the emergence time for sulfur dioxide and water can be readily controlled without materially affecting the emergence order for the other typical kraft mill compounds.

This present work has evolved from an attempt to resolve the various difficulties presented in the sampling and GLC analysis of pulp mill gaseous emissions. The method and equipment are designed for use with a gas chromatograph having a thermal detection cell. Miniaturization and modification of techniques should be considered if an ionization detector and/or Golay column were to be used.

## EXPERIMENTAL

### *Water Elimination*

Most of the waste-gas streams from pulping processes are either saturated or supersaturated with water at elevated temperatures. As much as 1400 ml. of water can be condensed from a cubic foot (STP final volume) of certain of the effluent gases. This same volume of

effluent gas might contain from 1 to 200 mg. of a malodorous compound such as hydrogen sulfide. Obviously, water must be removed in order that the odors may be effectively concentrated.

Cave used a spiral condenser trap immersed in ice-water to remove the major portion of the water found in the pulp mill gases (*7*), Fig. 1. The present authors have found that some odorous material is condensed with the water during the sampling of mill sources. Potentiometric titration of a portion of a condensate obtained from a furnace recovery stack indicated that no $H_2S$ or $CH_3SH$ was retained in the condensate. Other sulfur compounds were present, however, and were equivalent to approximately 15 p.p.m. of sulfur calculated as $SO_2$. Additional work will be required to identify these odoriferous materials and to assess their significance in the overall kraft odor complex.

*Fig. 1. Water condenser trap*

It was found that the water vapor in the air emerging from the "Cave" trap at 0°C. would elute sulfur compounds from a silica gel column held at −78.5°C., Fig. 2. Therefore, it was necessary to remove additional water from the gas stream prior to adsorption on the silica gel adsorption column. Use of a solid desiccant as a secondary drying step was next investigated.

West, *et al.* (*30*), used magnesium perchlorate to remove water vapor from the air prior to adsorption of organic pollutants on activated charcoal. However, an earlier report by Stross and Zimmerman (*22*) indicated that the use of magnesium perchlorate as a drying agent for gases containing organic compounds even at room temperature was extremely dangerous. Of the many drying agents available, Drierite (anhydrous calcium sulfate) appeared to be the least likely to react with sulfur gases in the pulp mill emissions. Subsequently, Farrington, *et al.* (*12*), reported that anhydrous potassium carbonate retained fewer of the "Los Angeles-type" smog constituents than did five other commonly used dehydrating agents including Drierite. Comparisons of recovery furnace samples have shown that

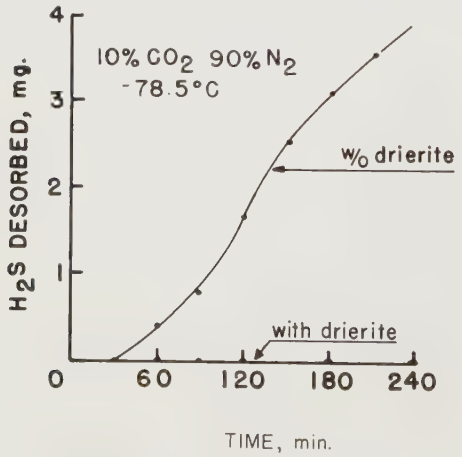


*Fig. 2. $H_2S$ desorption isotherms, effect of $H_2O$ removal*

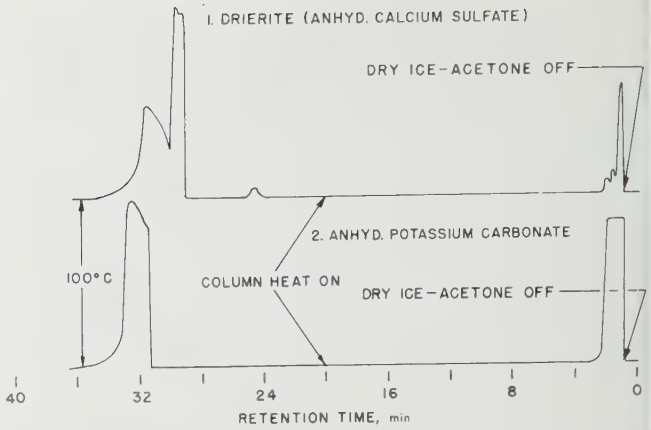


*Fig. 3. Desiccant residuals heat—vacuum desorption*

anhydrous potassium carbonate may be somewhat superior to Drierite, in some respects, for this present application (Fig. 3). Laboratory studies of $H_2S$, $SO_2$ and $CH_3SH$ recovery from potassium carbonate indicate, however, that Drierite is to be preferred.

A series of recovery experiments was conducted in which known weights of $H_2S$, $SO_2$, and $CH_3SH$ were passed through (a) an empty column, and (b) 10 g. Drierite maintained at room temperature and 55°C. These data are recorded in Table II. Based on these tests, it appeared necessary to maintain the Drierite at an elevated temperature to minimize surface adsorption of certain compounds by the desiccant. However, higher temperatures reduced the drying capacity of the Drierite and permitted water vapor to pass in sufficient quantity to initiate elution of sulfur compounds from the gel. The optimum temperature was found to be 55°C. Drierite at this temperature removed sufficient water from an air stream saturated with water at 0°C. to prevent elution of sulfur compounds adsorbed on a silica gel column held at −78.5°C. The desorption isotherm for $H_2S$ on silica gel under these conditions is also shown in Fig. 2. These experiments showed that sufficient water could be successfully removed from process emission streams by the dual process of condensation and desiccation.

### *Air Elimination*

Air will not be preferentially adsorbed on silica gel at −78.5°C. in the presence of polar compounds, although gas chromatographic evidence of air adsorption, *per se*, has been obtained (*25*).

### *Carbon Dioxide Elimination*

Carbon dioxide may constitute 10% or more of a recovery furnace effluent. The ratio of carbon dioxide to malodorous stack gas constituents must be materially reduced if the adsorbed stack sample is to be subsequently analyzed by gas chromatographic techniques. Theoretical consideration of the dipole moment of carbon dioxide indicated that $CO_2$ should be less strongly adsorbed on silica gel than the sulfur gases.

**Table II. Recovery of Sulfur Compounds from Drierite**

| | Recovery, % | | | | | |
|---|---|---|---|---|---|---|
| | Room temperature | | | 55°C. | | |
| *Compound* | *Empty tube* | *Drierite* | *Wet Drierite* | *Empty tube* | *Drierite* | *Wet Drierite* |
| Methyl mercaptan | 99.0 | 100.1 | 100.2 | 100.0 | 98.6 | 100.2 |
| Sulfur dioxide | 100.0 | 98.4 | 100.6 | ... | 98.9 | 99.3 |
| Hydrogen sulfide | 94.2 | 97.8 | 98.2 | 100.0 | 100.8 | 98.6 |

Substantiation of this consideration was furnished by information concerning the Reich (*18*) process for carbon dioxide purification with silica gel. In this process the odorous impurities in the carbon dioxide-containing gases arising from the brewing of beer are adsorbed on silica gel. The effluent stream from the gel consists of air and purified carbon dioxide.

To test the hypothesis that $CO_2$ might pass unadsorbed through silica gel, a $^1/_4$-in. o.d. "U" tube containing 3 in. of silica gel was placed in the gas chromatograph. Carbon dioxide was introduced onto the column and the time required to elute the $CO_2$ was determined at a number of column temperatures in the range of −78.5°C. to 30°C. This disclosed that $CO_2$ would be retained indefinitely at −78.5°C. However, it was subsequently found that $CO_2$ adsorption would not interfere with the adsorption of more polar compounds.

Although complete separation of $CO_2$ from the sulfur compounds is not possible in this manner, a major degree of fractionation was obtained. Once the silica gel becomes $CO_2$-saturated, additional $CO_2$ in the gas sample passes on through the column, thus reducing the ratio of $CO_2$ to sulfur compounds in the adsorbed sample.

### *Silica Gel Absorption*

Although silica gel has been used in air pollution sampling for "Los Angeles-type" smog constituents (*11*), etc., its use for collecting sulfur compounds of the kraft mill type has not previously been reported. The dipole moments of the sulfur compounds (Table I) previously identified by mass spectrographic analysis (*13*) and other products theoretically present in kraft mill effluents, indicated that they should be absorbed in the following approximate order:

$$H_2O > SO_2 > CH_3SH > CH_3SCH_3 > H_2S > ClO_2 > N_2O_4 > NO_2 > CO > CO_2 > Cl_2 > N_2 > O_2$$

Since it had been previously established that silica gel at −78.5°C. would adsorb $CO_2$, the following experiment was designed to determine the adsorptive capacity of $CO_2$-saturated silica gel for sulfur compounds. Silica gel columns were saturated with $CO_2$ at −78.5°C. The columns were then transferred to the gas chromatograph, maintaining the column −78.5°C. temperature. Five milliliters of $H_2S$, $SO_2$, $CH_3SH$, $(CH_3)_2S$, and $(CH_3S)_2$ were added to the column singly and in mixtures and carrier helium run through for periods up to 2 hrs. No evidence of elution of the sulfur compounds was observed on the continuous chromatographic record. The dry ice-acetone Dewar was then removed from the column and the temperature increased. The emergence of the requisite peaks on the chromatographic record showed that the various malodors had been adsorbed and retained on a $CO_2$-saturated silica gel column at −78.5°C.

In addition to the chromatographic evidence, titrimetric evidence was obtained which confirmed that $H_2S$ would be quantitatively adsorbed and retained on $CO_2$-saturated silica gel at −78.5°C. An impinger bottle containing a dilute solution of NaOH was attached to the downstream side of the silica gel tube on which $H_2S$ had been adsorbed. Nitrogen carrier gas containing 10% $CO_2$ was passed through for 2 hr. The scrubbing solution was then potentiometrically titrated with standard silver nitrate. There was no evidence of loss of $H_2S$ from the gel. Under conditions of extended sampling rates some "leakage" of $H_2S$ may be encountered. In this instance the use of a final ammoniacal cadmium trap is recommended. This solution may then be analyzed by the conventional iodometric technique.

Samples of $H_2S$ were then passed through silica gel columns at −10°C. using three different carrier gas streams, 100% $N_2$, 10% $CO_2$–90% $N_2$, and 100% $CO_2$. Figure 4 shows the varying degrees of retention of $H_2S$ at −10°C. on silica gel with the three carrier gases. That $CO_2$ has an eluting influence on the gel-adsorbed $H_2S$ at ice-salt temperatures is readily apparent.

Further comparison of the influence of $CO_2$ on the desorption of $H_2S$ from silica gel at ice-salt and dry ice-acetone temperatures is shown in Fig. 5. These data show that $CO_2$ will elute $H_2S$ at −10°C., but not at −78.5°C. It is necessary to cool the silica gel trap to the dry ice-acetone temperature (−78.5°C.) to insure quantitative trapping of the lower boiling point compounds such as $H_2S$ and $CH_3SH$. Under these temperature conditions collection of the pulp mill waste gases will result from increasing condensation as well as surface adsorption.

This series of experiments showed that $CO_2$ was adsorbed under the conditions necessary to assure retention of the sulfur compounds (−78.5°C.). They showed further that sulfur compounds would be adsorbed on $CO_2$-saturated gel, and that $CO_2$ would not elute adsorbed sulfur compounds from the gel at −78.5°C.

### *Sample Desorption*

Once the sample has been collected on the silica gel, it must then be quantitatively removed for subsequent analysis. Previous investigators have desorbed air pollutants from activated charcoal at 200°C. and atmospheric pressure (*30*) and at 100 to 250°C. and 1 $\mu$ pressure (*27*). Edgar and Paneth (*11*) desorbed ozone

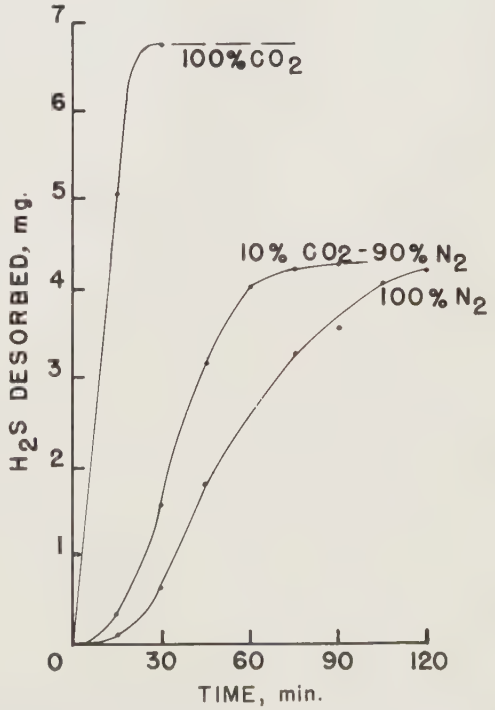


*Fig. 4. $H_2S$ desorption isotherms, −10°C., $CO_2$ influence*

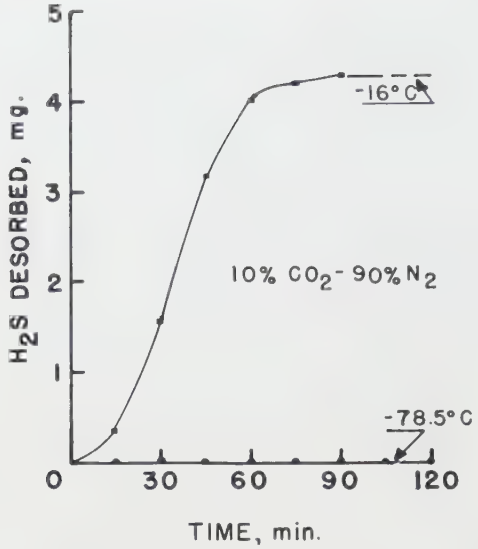


*Fig. 5. $H_2S$ desorption isotherms, effect of temperature*

and oxides of nitrogen from silica gel at −78.5°C.

The initial desorption experiments were conducted at elevated temperatures. Methyl mercaptan (8.34 mg.) was adsorbed at −78.5°C. on silica gel and then desorbed at 150 to 270°F. Figure 6 shows typical desorption isotherms obtained at four temperatures. The best recoveries (approximately 80%) were obtained in a temperature range of 100 to 130°C. (210 to 270°F.) and 60 min. desorption time. Figure 7 illustrates the rate of recovery of $CH_3SH$ from empty tubes and tubes containing silica gel, glass beads, and sand under heat desorption conditions. These desorption experiments were conducted to establish the range of adsorption on the system surface which was being experienced. Similar desorption recovery efficiencies were obtained at room temperature and 0.2 mm. Hg pressure. Desorption at 115°C. and 0.2 mm. Hg pressure gave an average recovery of 95%. Additional experiments showed 97.4% recovery of $H_2S$ and 103% for $SO_2$.

These experiments show that satisfactory desorption of such known compounds from silica gel could be obtained under conditions of 115°C. and 0.2 mm. Hg pressure using equipment as illustrated in Fig. 8.

### *Field Sampling Kit*

The field sampling kit was designed to contain the condensing, drying, and adsorbing traps and accessories in a convenient and portable manner. The major details of the sampling train are schematically

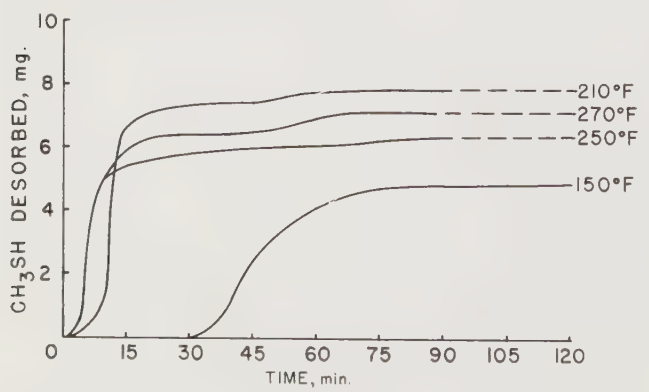


*Fig. 6. Heat desorption isotherms—$CH_3SH$ from silica gel*

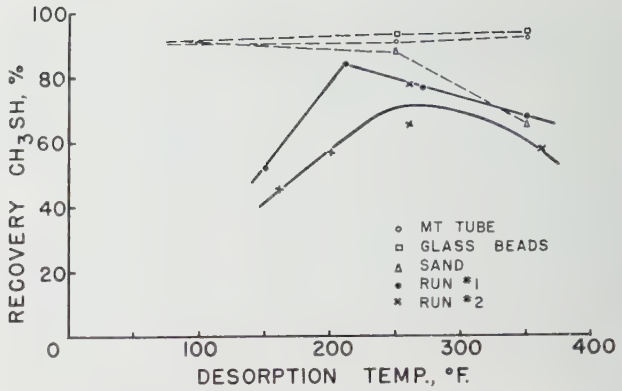


*Fig. 7. Desorption temperature versus recovery (60 min.)*

shown in Fig. 9, and are similar in certain respects to those proposed by Cave (*7*). The kit-carrying case measures 11½ by 23 by 29 in. and weighs approximately 36 lb. complete. The kit with face and top removed as it would be used in a mill survey is illustrated in Fig. 10. The face panel of the kit is shown directly below the kit. The heated sampling lines are mounted on the inside of this panel and provide a convenient carrying rack for these tubes when the case is not in use.

The sampling probe consists of a tubular fritted glass filter, coarse porosity, sealed to a 18/9 ball joint. Sampling probes of several lengths are provided for use in sampling stacks of various diameters. Selection of

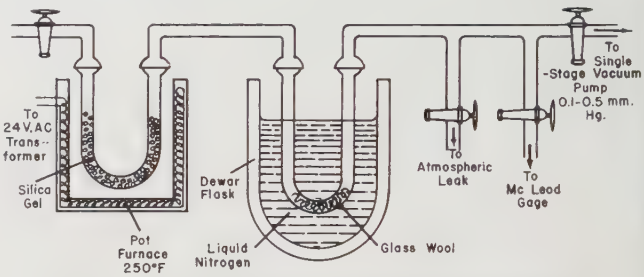


*Fig. 8. Apparatus for heat-vacuum desorption*

probe length is made to allow the ball joint to be located just outside of the stack port. The probe is connected to a series of 2 ft. ball and socket tubes and 90° or 105° ball and socket elbows as required to conduct the stack gas to the kit. The 2-ft. tubes and elbows are wrapped with glass cloth-covered heating tape ("Heat-by-the-yard") series-connected to a variable transformer. The heaters permit the sample lines to be maintained just above the dew point of the source being sampled. All ball and socket joints are fastened together with no. 18 pinch clamps.

The final tube or "el" in the sampling line is connected to the "Cave" water condensing trap immersed in an ice-water Dewar flask. An orifice flow meter is attached to the "Cave" trap with a ball and socket joint. This in turn is connected to the desiccant "U"

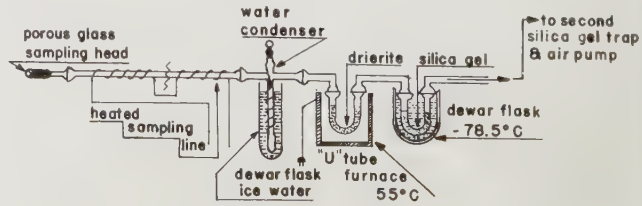


*Fig. 9. Apparatus for adsorption sampling*

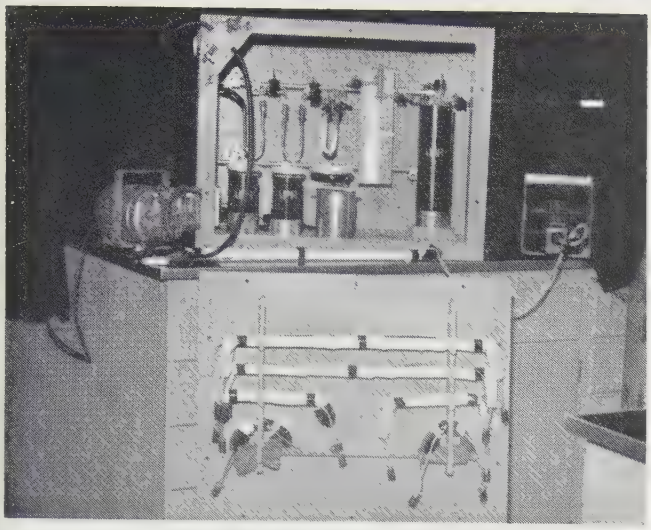

*Fig. 10. Field sampling kit*

tube by means of ball and socket joints. The desiccant (Drierite or anhydrous potassium carbonate) is maintained at 55°C. in the "U" tube furnace. Approximately 10 g. of desiccant, 20 to 40 mesh, is placed in the $^{7}/_{16}$-in. i.d. U tube. A small wad of glass wool is placed in each end to keep the desiccant in place.

The silica gel columns are prepared by filling a 10 by $^{1}/_{4}$ in. o.d. stainless steel tube with a 9-in. column of 28 to 60-mesh silica gel (Fisher No. S-157). The silica gel is held in place by small wads of glass wool at either end. The column is then bent in a "U" shape to fit directly into the gas chromatograph. The desiccant tube is connected to the first silica gel tube with a U-shaped adapter having an 18/9 socket to match the 18/9 ball on the downstream end of the drying tube. The other end of the adapter consists simply of a $^{1}/_{4}$-in. o.d. tube which is connected to the silica gel tube with a $^{1}/_{4}$-in. stainless steel Swagelok union. Polyethylene ferrules are used on the glass tip to make a nonbreaking seal. (Swagelok fittings are recommended because the unique double ferrule permits tightening the joint without twisting the metal tubing or breaking the glass tubing.)

The second silica gel U tube is connected to the first U tube by means of a stainless steel U-shaped $^{1}/_{4}$-in. o.d. adapter with Swagelok unions. Both silica gel U tubes are immersed in dry ice-acetone Dewars to maintain the temperature of the gel at −78.5°C. The second silica gel tube is used as a precautionary measure. Subsequent work may prove it unnecessary.

The second silica gel U tube is connected to an air-leak bypass tube with rubber tubing. This in turn is connected by rubber tubing to a $\frac{1}{6}$ hp., Gast air pump. The flowrate is manually adjusted by regulating the pressure of a Hoffman clamp on the air leak tube. The flowrate is indicated by the orifice flowmeter.

## RECOMMENDED PROCEDURE FOR SAMPLING AND ANALYSIS

### *Sampling*

The silica gel and desiccant U tubes are flushed with dry nitrogen in the laboratory at 120°C. for 15 min. to remove any accumulated water. The tubes are then cooled in a desiccator. When the tubes are cool, they are sealed to prevent adsorption of water from the ambient air prior to use. The glass U tubes are sealed

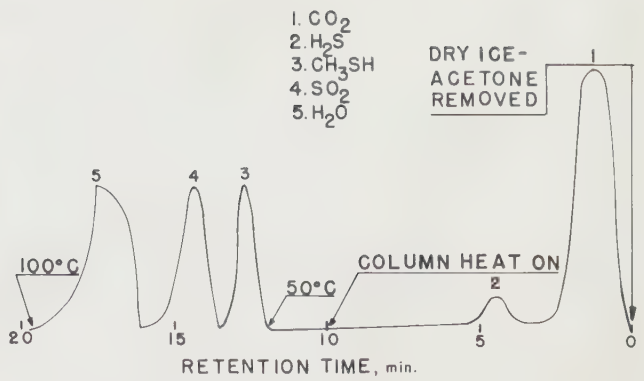


*Fig. 11. Typical elution curve—silica gel column*

with 18/9 joints which have been sealed as close to the joint as possible. The seals are held to the U tube with no. 18 pinch clamps. Swagelok caps seal the stainless steel silica gel U tubes. An adequate supply of these tubes are prepared in advance in the laboratory.

The usual measurements of flowrate and temperature of the effluent in the duct or stack are made as conditions dictate. Mill operating conditions are checked and recorded.

The carrying case is positioned near the sampling port. The sampling line is installed using heated sampling tubes and "els" as required. The sampling line should be adequately supported with ring stands and clamps or other devices to insure a stable setup.

The Dewar flask surrounding the "Cave" trap is filled with crushed ice and then filled with water. The two Dewar flasks associated with the silica gel tubes are filled with crushed dry ice and filled with precooled acetone. Care must be taken to prevent acetone from splashing on the ground glass joints and stainless steel connections.

The desiccant and silica gel tubes are uncapped and connected in the sampling train. The U tube furnace and sample line heaters are connected to a power source. The variable transformer is adjusted to maintain the sampling tubes at a temperature slightly above the dew point of the effluent to be sampled. The sampling probe is then inserted through the sampling port, using the proper-length probe to obtain the sample from the desired location within the stack or duct. The probe is attached to the sampling tube with a pinch clamp.

The air-leak hose clamp is opened and the air pump

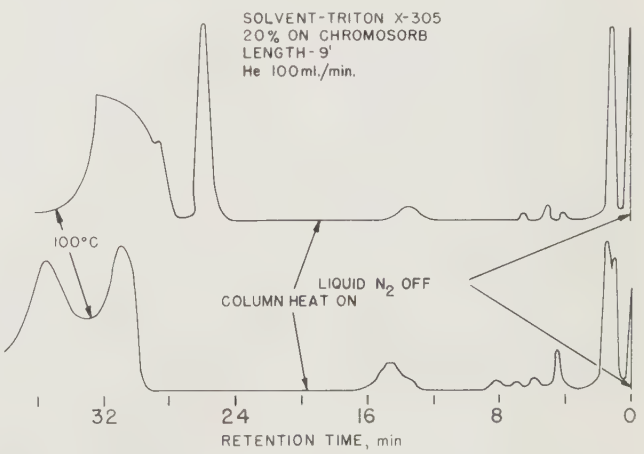


*Fig. 12. Chromatograph desorption and preseparation*

turned on. The hose clamp is then slowly closed until the desired sampling rate has been established as indicated by the flowmeter. The sampling rate chosen will depend upon the anticipated pollutant concentration range in the effluent gas. Sampling rates in the range of 50 to 100 ml. per min. are possible with the train as described without encountering an excessive pressure drop across the system, although the lower rates are preferred. The pressure drop through the sampling train is obtained from a manometer or vacuum gage mounted at the downstream end of the train.

At the end of the sampling period, the silica gel columns are detached from the system and immediately sealed. The tubes are kept in the dry ice-acetone bath until time of analysis. (An alternative procedure would permit the tightly sealed silica gel tubes to be transported at ambient temperatures to a distant laboratory. The adsorbed sample would be desorbed under conditions of heat and vacuum into a liquid nitrogen-cooled trap and then introduced onto a conventional GLC column.) The used desiccant tube is removed from the sampling train and replaced with a fresh tube. The used drying tubes are returned to the laboratory for water removal at 120°C.

### *Qualitative Analysis*

The silica gel tube, maintained at −78.5°C., is uncapped and immediately attached to the chromatograph. The column must be installed so that the leg which was upstream during the sampling is in the same position in the chromatograph. The tube is flushed with the helium carrier gas to displace any noncondensable gases in the interstices of the silica gel. The flow of helium is allowed to continue so as to develop the chromatogram. The dry-ice Dewar is then removed and the column permitted to warm up to ambient temperature. Carbon dioxide, nitrogen, and oxygen are eluted almost immediately. Hydrogen sulfide elutes at room temperature. Following appearance of the hydrogen sulfide peak, the column heater is turned on and the temperature of the silica gel column is elevated to 100°C. A typical chromatogram of a mixture of malodorous sulfides, as it is eluted from the silica gel, is shown in Fig. 11.

Following the appearance of the elution peaks of the noncondensable gases, the remaining elutants may be retrapped as a unit (or fractionated) by passing the eluted stream through a liquid nitrogen-cooled trap(s). The retrapped sample(s) may then be re-chromatographed on any conventional GLC column (*1–3, 7, 8, 15, 16, 19, 21, 23*). A typical curve of a re-chromatographed recovery furnace sample is shown in Fig. 12.

Re-chromatographing is found to be a desirable step when working with unknown mixtures as well as with known mixtures chromatographed on silica gel which show ill-defined elution peaks. The additional resolution thus afforded is readily seen through comparison between Figs. 10 and 11.

Although excellent desorption of known sulfur compounds from silica gel was obtained in the laboratory, it has been noted that the silica gel used in sampling a recovery furnace stack becomes discolored. Apparently an as yet unidentified component of the recovery furnace effluent is not completely desorbed under the conditions described above. An aromatic-type odor is exuded from the used gel. It is therefore recommended that fresh silica gel be used for each sampling. The contribution of this unidentified adsorbate to the overall pulp mill odor complex has not yet been established.

### *Quantitative Analysis*

For quantitative recovery of malodors from activated silica gel, the sample must be desorbed under conditions of heat and vacuum, 100–200°C. and 0.2 mm Hg, as previously described. The desorbate is trapped at −195.8°C. in a Shepherd trap (20) and is then transferred onto a GLC column for analysis. This method of desorption does not provide for an initial separation of $CO_2$ from the malodors. The first chromatographic peak to appear represents an unresolved mixture of $CO_2$ and $H_2S$. This mixture can be absorbed in dilute NaOH and titrated potentiometrically with standard $AgNO_3$ to determine the $H_2S$ content of the sample.

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# ASSOCIATION NEWS AND EVENTS

## National Conferences

***1960***

*Ninth Statistics Course*, Aug. 8–19, 1960, Brevard College, Brevard, N. C.

*Fourteenth Alkaline Pulping Conference*, Aug. 22–24, 1960, Multnomah Hotel, Portland, Ore.

*Forest Biology Conference*, Aug. 24–27, 1960, New Washington Hotel, Seattle, Wash.

*Eleventh Testing Conference*, Sept. 27–29, 1960, Pantlind Hotel, Grand Rapids, Mich.

*Fifth Deinking Conference*, Oct. 5–7, 1960, Conway Hotel, Appleton, Wis.

*Tenth Corrugated Containers Conference*, Oct. 10–13, 1960, Royal York Hotel, Toronto, Ont.

*Fifteenth Plastics Conference*, Oct. 17–19, 1960, Syracuse Hotel, Syracuse, N. Y.

*Fifteenth Engineering Conference*, Oct. 24–28, 1960, Robert Meyer Hotel, Jacksonville, Fla.

*Fundamental Research Conference*, Nov. 3–5, 1960, Northampton Hotel, Northampton, Mass.

***1961***

*46th Annual Meeting*, Feb. 19–23, 1961, Commodore Hotel, New York. N. Y.

*Twelfth Coating Conference*, May 15–17, 1961, Statler-Hilton Hotel, Buffalo, N. Y.

*Twelfth Testing Conference*, Aug. 15–18, 1961, Queen Elizabeth Hotel, Montreal, Que.

*Eleventh Corrugated Containers Conference*, Sept. 11–13, 1961, St. Francis Hotel, San Francisco, Calif.

*Fourteenth Mechanical Pulping Conference*, Sept. 19–21, 1961, Edgewater Beach Hotel, Chicago, Ill.

*Symposium on Formation and Structure of Paper*, Sept. 25–29, 1961, B.P.B.M.A., Oxford, England.

*Sixteenth Plastics Conference*, Oct. 9–11, 1961, French Lick Sheraton Hotel, French Lick, Ind.

*Sixteenth Engineering Conference*, Oct. 15–19, 1961, Shoreham Hotel, Washington, D. C.

*Fifteenth Alkaline Pulping Conference*, Nov. 1–3, 1961, Rice Hotel, Houston, Tex.

***1962***

*47th Annual Meeting*, Feb. 18–22, 1962, Commodore Hotel, New York, N. Y.

*Thirteenth Coating Conference*, May 14–16, 1962, Netherland-Hilton Hotel, Cincinnati, Ohio.

*Thirteenth Testing Conference*, Sept. 18–20, 1962, Benjamin Franklin Hotel, Philadelphia, Pa.

*Seventeenth Engineering Conference*, Oct. 14–19, 1962, Queen Elizabeth Hotel, Montreal, Que.

*Twelfth Corrugated Containers Conference*, Oct. 23–26, 1962, Statler-Hilton Hotel, Boston, Mass.

*Sixteenth Alkaline Pulping Conference*, 1962, Savannah, Ga.

***1963***

*Fourteenth Coating Conference*, May 19–22, 1963, French Lick Sheraton Hotel, French Lick, Ind.

*Thirteenth Corrugated Containers Conference*, Oct. 22–25, 1963, Statler-Hilton Hotel, Detroit, Mich.

*Eighteenth Engineering Conference*, 1963, Chicago, Ill.

## Testing Instruments Exhibit

The Eleventh Testing Conference will feature an exhibit of instruments of those manufacturers or dealers who are interested in displaying their equipment. Because of the Conference's important symposium on relative humidity, manufacturers of relative humidity measuring and controlling equipment in paper test rooms are also invited to participate.

The annual testing conference sponsored by the Pulp and Paper Industry will be held at the Pantlind Hotel, Grand Rapids, Mich., Sept. 27 through 29, 1960. Those interested in participating in this exhibit should contact A. J. Winchester, Technical Secretary, TAPPI, 360 Lexington Ave., New York City.

## Corrugated Containers Conference

Program for the 10th Corrugated Containers Conference indicates an outstanding event filled with technical interest and relaxing social activities. This Corrugated Containers Conference, the first to be held in Canada, takes place in the Royal York Hotel, Toronto, Ont., starting on Oct. 10, 1960.

Jointly sponsored by TAPPI and the Technical Section of the CPPA, the conference is being organized and planned by a joint Association committee under the chairmanship of Ralph Buttery, Director of Manufacturing, Bathurst Containers, Ltd., Montreal.

The theme of the first day's program is Printing on Corrugated Board and will be moderated by Dwight M. Davis, Hercules Box Co., Columbus, Ohio. Papers will be given on "Printing Press Rollers Designed for Corrugated Printing," by Geo. A. Browne, Permaflex Industries, Toronto; "Printing Dies for Corrugated Board," by Robert Reid, General Printing Ink Co., Cincinnati, Ohio; and "Printing Dies for Corrugated Board," by Harry Devon, Jas. A. Mathews & Co., Pittsburgh, Pa.

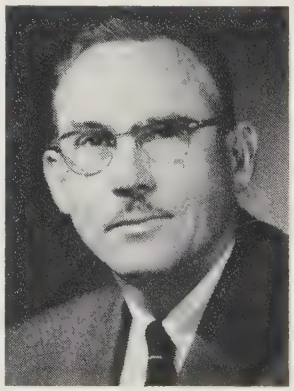
Following these papers a moving picture will be shown demonstrating proper adjustments and use of materials to obtain top quality and reduce cost.

"New Developments in Packaging" is the theme for the morning of the second day under Moderator Henry J. Ostrowski, Hinde and Dauch, Ltd., Toronto. Papers will be given on "Corrugated Containers under Refrigeration," by A. C. Beardsell, Cincinnati, Ohio, "Bulk Packaging," by T. C. Kitchell, Union Bag-Camp Paper Corp., New York, and "Dynamic Testing of Corrugated Packages," by Dr. John Turk, Glass Containers Manufacturers Institute.

In the afternoon J. G. Reynolds, Bathurst, Containers, Montreal, will speak on "The Bathurst Method for Determination of Corrugater Starch Consumption." In addition to these technical papers and features others will be added in the near future.

The final day of the conference will be tours of plants in Toronto, Hamilton and Surrounding Areas.

An outstanding program has been arranged for the ladies consisting of special hospitality rooms, tours of the city and an all-day tour to Niagara Falls.



***Ralph Buttery, general chairman, 10th Corrugated Containers Conference***

Plan now to attend this conference and visit Canada when the countryside is at its colourful best.

## *1960 Summer Meeting, Technical Section Canadian Pulp and Paper Association*

The Banff Springs Hotel, at Banff, Alberta, will be the scene of the 1960 Summer Meeting of the Technical Section, Canadian Pulp and Paper Association. Sessions will begin at noon on Tuesday, Sept. 6, 1960, and will end at noon on Friday, Sept. 9, 1960.

This meeting will differ somewhat from Summer Meetings of the past in that a theme has been chosen entitled "Towards the More Complete and Efficient Use of our Raw Materials and Manpower Resources." Sessions will be chosen to fit in with this theme and, if possible, there will not be more than one session held at a time. In addition, a visiting delegation from the British Technical Section will be present.

The program for the meeting has not yet been finalized, but all the various committees of the Technical Section are currently engaged in preparing their portions of the program which will provide topics of interest to those engaged in all phases of pulp and paper manufacture.

As has been the policy at previous meetings, the Technical Section will welcome nonmembers who wish to attend the Summer Meeting.

Please note that the Technical Section is unable to handle requests for accommodation. All reservations should be made through D. A. Williams, Manager, Banff Springs Hotel, Banff, Alberta.

## *Ninth Statistics Course*

Application forms are now available for the 9th Pulp and Paper Statistics Course, which is jointly sponsored by the Technical Section, Canadian Pulp and Paper Association, and the Technical Association of the Pulp and Paper Industry, and will be conducted by the Institute of Statistics, North Carolina State College, Aug. 8–19, 1960.

### *Basic Section*

This section of the course will cover the basic concepts of statistics in a series of 18 lectures and a like number of laboratory sessions based on practical examples from the pulp and paper industry. Little or no previous acquaintance with statistics will be assumed, and the level of presentation will be fairly elementary. The text used will be O. L. Davies' "Statistical Methods in Research and Production," (3rd Edition).

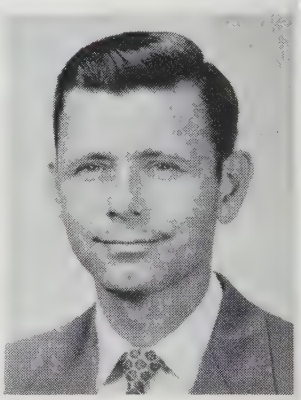
Topics to be covered include:

1. Concepts of random variation and its quantitative description.
2. Sampling variation in means and standard deviations.
3. Sampling variation in the difference between two means and in the ratio of two standard deviations.
4. Confidence limits and significance testing.
5. Introduction to analysis of variance.
6. Basic principles of quality control.
7. Fitting of straight lines by least squares.
8. Fitting of polynomials and equations with several variables.
9. Introduction to response surface methodology.
10. Introduction to design of experiments including randomized blocks, latin squares, and simple factorials.

### *Advanced Section*

This section is intended for people who already have an understanding and some experience in application of the basic section topics. A series of coordinated lectures will be given on each of several somewhat more advanced topics. Laboratory practice and discussion sessions are also planned. Opportunity will be available for students to discuss statistical problems of their own with the instructors and with the group.

Requests for forms should be addressed to Dr. R J. Hader, The Institute of Statistics.



*Prof. R. J. Hader*

### *Limited Enrollment*

Enrollment will be limited to 40 students in the Basic Section and 25 in the Advanced Section. First preference will be to people from the pulp and paper industry; others will be accepted if space is available.

### *Registration Fee*

A registration fee of $275 will be charged. This includes board and room for the two-week period as well as textbook and other materials. The registration fee should be paid in advance to Division of College Extension, North Carolina State College, Raleigh, N. C.

## APPLICATION

**NINTH PULP AND PAPER STATISTICS COURSE**

Name _____

Company _____

Address _____

_____

Professional Position _____

☐ Basic Section ☐ Advanced Section*

Accommodations Desired: ☐ Single ☐ Double ☐ Family

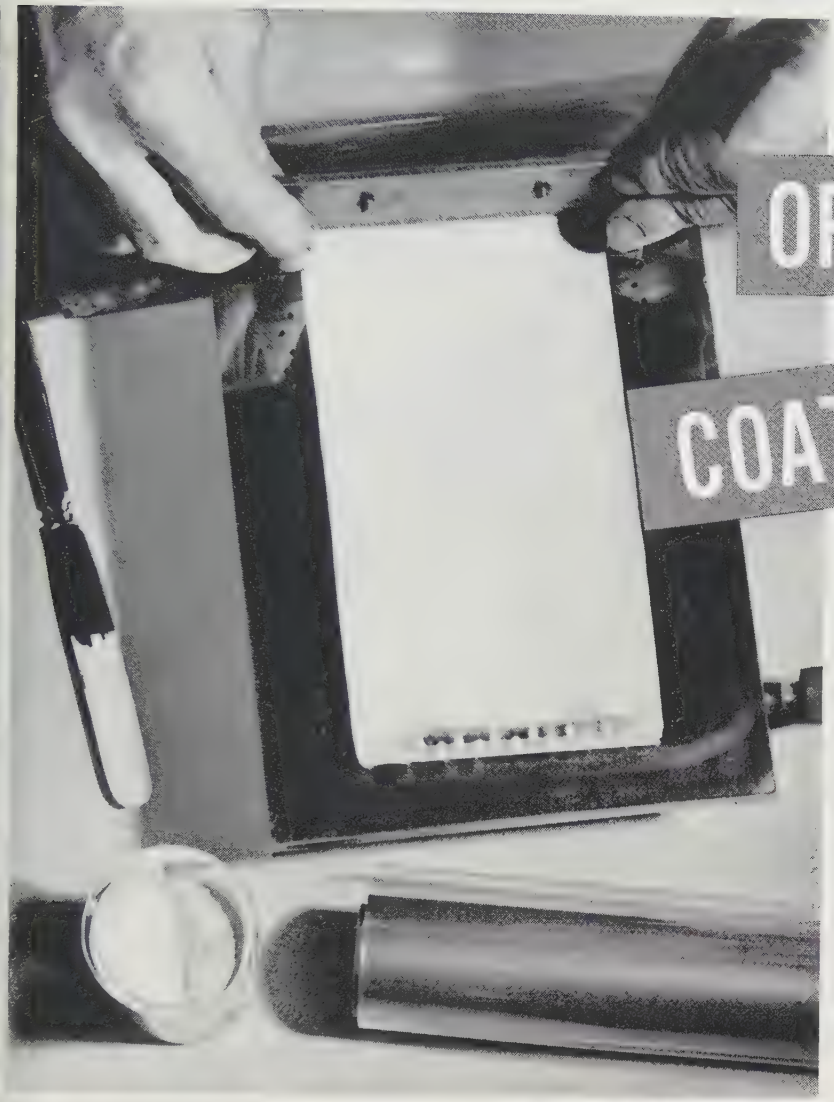
No. in Family _____

Make checks payable and mail to:

Division of College Extension
Box 5125
Raleigh, North Carolina

* **Anyone in doubt regarding the suitability of his background for enrollment in the advanced section should discuss the matter by correspondence with Dr. R. J. Hader.**

*From the Paper Research Laboratory of The New Jersey Zinc Company*
ONE *of a Series of Test Procedures on Horse Head Titanium Dioxide*



# OPACITY OF COATING COLORS

New Jersey Zinc paper technicians have developed this simple, quick and accurate test method for measuring the opacity of coating colors. This eliminates the influence of the substrate and permits highly accurate study of the factors responsible for opacity in coating colors.

Such test procedures and the results obtained through their application play an important role in the development of new knowledge on the function of titanium dioxides in paper products. They serve, too, in maintaining the high quality and uniformity standards of HORSE HEAD titanium dioxides.

Employing a specially designed stainless steel suction box and a Bird applicator, technicians prepare uniform films of coatings on cellophane sheets to be tested for opacity on a spherical reflectometer.

## HORSE HEAD® TITANIUM DIOXIDE

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*Also Distributed by* BULKLEY DUNTON PULP CO. INC. • New York, N. Y. • Kalamazoo, Mich.

*Course Location*

The course will be held on the campus of Brevard College located approximately 25 miles south of Asheville in the mountains of Western North Carolina. Students will be housed in the new modern dormitories and meals served at the college cafeteria. A limited number of accommodations are available for families. Rates will be furnished on request.

Recreational facilities in the Brevard area include golf, fishing, swimming, riding, and hiking. The Pisgah National Forest, Great Smoky Mountain National Park, and the city of Asheville are within easy driving distance. The Brevard Music Festival is widely known for its fine music.

Visits to near-by paper mills will be arranged if desired.

## *TAPPI Forest Biology Conference*

The TAPPI Forest Biology Conference will be held Aug. 24–27, 1960, at the New Washington Hotel in Seattle, Wash. The Forest Biology Conference has been scheduled so that interested parties can also attend the Fifth World Forestry Congress, scheduled for the University of Washington campus in Seattle, August 29 through September 10. This international meeting of forestry authorities—many of whom are world-famous—is the first Congress for which the United States has been host, and the first ever held in the Western Hemisphere. Two hundred authorities will speak on every aspect of forestry from surveying virgin timber lands to developing new uses for woods already reaching world markets.

R. J. Seidl, Simpson Timber Co., Seattle, Wash., general conference chairman, has announced the theme "Better Fibers from Better Trees Through Forest Biology," and has released a tentative program. J. W. Duffield, W. B. Greely Forest Nursery, Nisqually, Wash., is chairman of the technical program committee. He is being assisted by B. J. Zobel, School of Forestry, North Carolina State College, Raleigh, N. C.; B. A. Jayne, Washington State Institute of Technology, Washington State University, Pullman, Wash.; and V. P. van Buijtenen, The Institute of Paper Chemistry, Appleton, Wis.

R. Z. Callaham, Forest Service, U. S. Dept. of Agriculture, Spokane, Wash., is in charge of local arrangements and field trips. He is being assisted by R. F. Sultze, Simpson Timber Co., Seattle, Wash.

### WEDNESDAY, AUG. 24, 1960

**2:00 p.m. General Session (Windsor Ballroom)**

*Moderator:* D. D. Stevenson, Buckeye Cellulose Corp., Foley, Fla.

Introductory remarks.
Principal address by J. L. McCarthy, University of Washington, Seattle, Wash., and another guest speaker.

### THURSDAY, AUG. 25, 1960

**9:00 a.m. First Session (Windsor Ballroom)**

Theme: "Evaluation of Wood Properties"

1. "Dimensional Evaluation of Wood Fibers," by R. M. Echols, Southern Institute of Forest Genetics, U. S. Forest Service, Gulfport, Miss.
2. Three additional papers.

**1:00 p.m. Second Session (Windsor Ballroom)**

*Moderator:* H. E. Dadswell, Division of Forest Products, C.S.I.R.O., Melbourne, Australia

Panel Discussion: "Can Genetic Improvement of Wood Properties Keep Pace with Technology?"

Panel:
*Paper Technologists:* M. G. Lyon, Champion Paper and Fibre Co., Hamilton, Ohio, and others to be announced.
*Forest Biologists:* Several to be announced.

**6:00 p.m. Hospitality Hour (Flamingo Room)**

**7:00 p.m. Banquet (Windsor Ballroom)**

### FRIDAY, AUG. 26, 1960

**9:00 a.m. Third Session (Windsor Ballroom)**

Theme: "Variations in Wood Properties"
*Moderator:* M. D. McKimmy, School of Forestry, Oregon State College, Corvallis, Ore.

1. "Tree to Tree Variations and Gross Heritability of Wood Characteristics of *Pinus radiata*," by H. E. Dadswell, J. M. Fielding, J. W. P. Nicholls, and A. G. Brown; C.S.I.R.O., Melbourne, Australia.
2. "Anatomical Responses of Loblolly Pine to Soil Water Deficiencies," by D. M. Smith, Forest Products Laboratory, U. S. Forest Service, Madison, Wis.
3. "Effect of Fertilizer in Wood Properties of Loblolly Pine," by B. J. Zobel, F. Goggans, T. E. Maki, and F. Henson, School of Forestry, North Carolina State College, Raleigh, N. C.
4. "Variations in Wood of Yellow Poplar," by E. Thorbjornsen, University of Tennessee, Knoxville, Tenn.

**1:00 p.m. Fourth Session (Windsor Ballroom)**

*Moderator:* To be announced

Theme: "Influence of Wood and Fiber Properties on Pulp and paper Characteristics,"

1. "Pulp and Paper Processes and their Characteristic Differences," by H. W. Bialkowsky, Weyerhaeuser Co., Longview, Wash.
2. "Pulpwood Properties—Response of Processing and of Paper Quality to Their Variation," by E. F. Thode, The Institute of Paper Chemistry, Appleton, Wis.
3. "Relationships Between Hardwood Fiber Characteristics and Pulp Sheet Properties," by F. N. Tamolang, Bureau of Forestry, Manila, Philippines.

### SATURDAY, AUG. 27, 1960

Those planning to attend the Forest Biology Conference are urged to preregister using the form shown below. Additional forms may be obtained from TAPPI, 360 Lexington Ave., New York 17, N. Y.

***Preregistration for***
***TAPPI Forest Biology Conference***
**"Better Fibers from Better Trees Through Forest Biology"**
***New Washington Hotel*** ***Seattle, Wash.***
***August 24–26, 1960***

**Name** _____

**Company** _____

**Address** _____

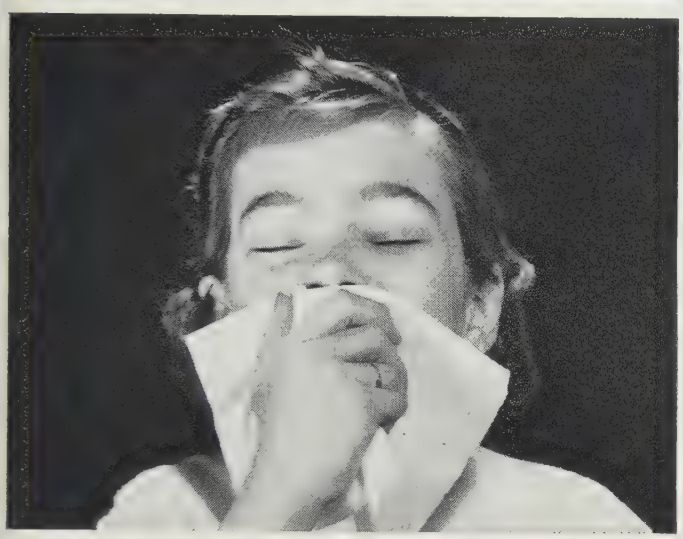
***Registration Fee $12.00***☐ ***Field Trip (Optional) $2.00***☐

***Total Enclosed*** ☐

***(Field trip tickets may also be purchased at the Conference). Registration fee must accompany the completed preregistration form. My Wife will accompany me: yes***☐ ***no***☐

***Make checks payable to*** **"TAPPI Conferences—W"** ***and mail before July 15, 1960 to:***

**R. Z. Callaham,**
**S. 157 Howard St.**
**Spokane 4, Wash.**



Need wet strength? . . . You'll find that one of the Rohm & Haas UFORMITE resins will suit your processing requirements and the end-use application—be it toweling, napkins, bag paper, butchers' wrap, paperboard, or a specialty item. Note the advantages exhibited by all three resins: 1) excellent storage stability, 2) immunity to sulfate ions, 3) ease of handling (no acid pretreatment or aging required), 4) easy broke recovery.

The properties of the individual resins are these: UFORMITE 700—high off-the-machine wet strength without attendant broke recovery problems. UFORMITE 711—efficient all-round performance at moderate cost. UFORMITE 467—maximum economy in unbleached grades of paper.

Write for our 24-page booklet, UFORMITE *Resins for Wet Strength Paper.*

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# UFORMITE

## *Annual Pulp and Paper Industry Electrical Engineering Conference*

The Sixth Annual Conference on Electrical Engineering as applied to the pulp and paper industry was held during April 21, 22, in the Auditorium of the Dan McCarty Hall on the extensive campus of the University of Florida. This conference was attended by 160 ranking electrical engineers from the mills and allied industries. Attendance was from widespread areas and included mill electrical engineers from as far north as Canada and as far west as Minnesota.

An interesting program of technical papers and timely addresses, directed at the improvement of technical operations in pulp and paper mills highlighted the 2-day conference. Inspection to the nearby paper mills and the University of Florida's continuous digester were ample to provide a well balanced and enlightening two-day program.

Jesse M. Yarbrough, engineer for the Mead Corp., Chillicothe, Ohio, was elected chairman of the Pulp and Paper Industry Subcommittee of the General Industries Committee of the AIEE. He replaces C. H. Hudson of the General Electric Co. in Atlanta. Other officers elected during the conference were: Charles L. Eletson, Hopper Paper Co., Taylorsville, Ill., vice chairman and John S. Kirkland, Rome, Ga., secretary.

Registration and special committee meetings of TAPPI and AIEE Subcommittee took place in Gainesville, Fla., prior to the first session of the conference.

Claude Hudson opened the conference and introduced Robert Mautz, dean of Academic Affairs at the University of Florida, who welcomed those attending the conference to the University campus. Mr. Mautz pointed out the University's dedication to the advancement of knowledge through research and partnership with applied industry for the advancement of scientific development, and explained that this represents "applied American ingenuity."

James J. Berry, chairman of the Jacksonville Section of AIEE, presided at the morning session, April 21, 1960.

Papers delivered during the morning session were: "Surge Protection in Paper Mills," by H. B. Greear, of General Electric in Atlanta, and "A Pulse-Digital Regulating System for Paper Machine Drives," by R. P. Derrick and C. L. Ivey, of Westinghouse Electric in East Pittsburgh.

Greear discussed the hazards of lightning and voltage surges to electrical systems and presented the methods used to avoid many problems created as a result of lightning and overvoltage.

Derrick and Ivey presented a new concept in paper machine drives, in the nature of a digital speed regulating system called Pulsetter.

This digital computer speed regulating system for sectional paper machine drives was later compared in a rebuttal, to the analog computing system by K. P. Grenfell of General Electric, Schenectady, N. Y., and by Bob Ferrell of Reliance Electric Co., Cleveland, Ohio. These gentlemen stated, in separate rebuttals, that the analog system, as used by their companies, was capable of the same operations as had been pointed out in the presentation of the new digital computer system.

Eugene W. O'Brien, managing director of Southern Power and Industry, Atlanta, Ga., was guest speaker at the Thursday luncheon. Mr. O'Brien explained that he had directed a survey at 1200 successful engineers less than five years out of college. The result of this survey, he revealed, is that significant majority of those contacted declared the human factors more important to success in the engineering field and that the minority choose technical factors. From this he concludes that more emphasis on the human factor and that young engineers should avoid becoming "nose to the grindstone" engineers.

The Thursday afternoon session was presided by E. H. Overby, Union Bag-Camp Paper Co., Savannah, Ga., and included presentation of a paper on "Crane and Hoist Systems" by Ken Jamison and Fred Fisher of Whiting Corp., Charlotte, N. C., and a panel discussion on "Low Voltage A.C. Motor Insulation."

***The group attending the Sixth Annual Conference on Electrical Engineering as applied to the pulp and paper industry***

Jamison and Fisher offered a set of rules to be used for selecting the proper cranes and electrical drives for crane service.

The panel discussion on low voltage a.c. motor insulation prompted a very interesting question-and-answer discussion between a panel of experts representing electrical manufacturers and the audience. The chairman for this panel was Earl K. Murphy, Rayonier, Inc., Jessup, Ga., and representatives on the panel were:

R. J. Dineen of the Allis-Chalmers Mfg. Co., Norwood, Ohio
E. W. Summers, Westinghouse Electric Corp., Buffalo, N. Y.
R. E. Arnold, General Electric Co., Schenectady, N. Y.
Earl C. Barnes, Reliance Electric and Engineering Co., Cleveland, Ohio
W. P. Gettleman, The Louis Allis Co., Milwaukee, Wis.

This panel discussion resulted in agreement that the new encapsulated a.c. motor has an accepted position in industry. Also pointed out was the fact that the encapsulation of a.c. motors will add to the temperature rise, and that there is no common standard designed for testing insulation on small motors of the encapsulated design.

The evening session followed a social hour, highlighting a humorous account of life in the "Nostalgic Past" by Rev. Hubert "Baldy" White of Atlanta, Ga.

During the second day of the conference, papers were presented by John R. Stevens of Champion Paper & Fiber Co., Canton, N. C.; R. D. Clarke, Brown Instrument Co., Philadelphia, Pa., and W. H. Buford, Container Board and Kraft Paper Div. of Continental Can, Hodge, La.

Mr. Stevens states that air conditioning will promote longer trouble-free periods and better quality paper as a result of the improvement of environmental atmospheric conditions by introduction of air conditioning.

Clarke emphasizes the advantage of newly transistorized testing and evaluating instruments which may be applied in paper industry process control. He also points out that an expansion will take place in the paper industry over the next few years which will provide many areas for new concepts in testing, data handling, and computation.

Buford stresses the importance of the selection and storage of critical parts and replacements for a paper mill electrical system. Combined with a good set of records giving the history of equipment involved, Mr. Buford states that a good job in this area is a *must* with every good maintenance program.

The 2-day meeting of this Sixth Conference was jointly

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## PREREGISTRATION FORM

**Fourteenth TAPPI Alkaline Pulping Conference**
Technical Association of the Pulp and Paper Industry

Aug. 22–24, 1960 Multnomah Hotel, Portland, Ore.

PLEASE PRINT OR TYPE

Name _____

First name or nickname preferred for name badge: _____

Company _____

Address _____ City _____ State _____

If accompanied by wife, wife's first name (for name badge): _____

★ *Make checks payable to:*
*Mail to:* Mr. J. L. McClintock
Weyerhaeuser Timber Co.
Longview, Wash.

★ REGISTRATION FEES ENCLOSED

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|---|---|
| Men (National TAPPI Member) | $15.00 |
| Men (nonmember) | 20.00 |
| Ladies' | 10.00 |
| Total Enclosed | $ _____ |

## HOTEL RESERVATIONS

PLEASE PRINT OR TYPE

Single..... Double ..... Twin.....

Name _____

Company _____

Address _____ City _____ State _____

Arrival Date _____ Time _____ Departure Date _____

Remarks _____

HOTEL ROOMS WILL NOT BE RESERVED UNLESS REGISTRATION FEE ACCOMPANIES THIS FORM. Preregistrations must be received by August 1 to assure accommodations. Room assignments will be mailed on or before August 10.

## INDUSTRIAL TOURS

PLEASE PRINT OR TYPE

Name _____

Company _____

Mill Tours—Wednesday, August 24: (Please check ONE)

_____ Crown Zellerbach Corp., Camas, Wash.
_____ Longview Fibre Co., Longview, Wash.
_____ Weyerhaeuser Co., Longview, Wash.
_____ Electric Steel Foundry Co., Portland, Ore.
_____ Pennsalt Chemicals Corp., Portland, Ore.
Accompanied by wife _____ children (No.) _____

Tree Farm Trip—Thursday, August 25:
A woods trip will be arranged if enough people want to go. An additional charge of $5.00 per person will be made, payable at the registration desk upon arrival.

Will you go on the woods trip? YES _____ NO _____

sponsored by the Pulp and Paper Subcommittee and the Jacksonville, Fla., Section of the American Institute of Electrical Engineers, and the Engineering and Industrial Experiment Station of the College of Engineering at the University. S. A. Bobe of Westinghouse Electric, Atlanta, served as chairman of the General Conference Committee. Committeemen were: L. E. Schoonmaker and W. R. D. Nickelson, University of Florida; C. H. Hudson, General Electric, Atlanta; R. P. Posey, Westinghouse, Jacksonville, and J. A. Womack, Owens-Illinois Glass Co., Jacksonville.

This very successful Sixth Annual Conference was a result, in a large part, to the contribution by the members of the General Conference Committee, and especially the fine cooperation by colleges and individuals of the University, including excellent publicity coverage locally, at the direction of Miss Rachel Albertson, editor of the College paper.

The Seventh AIEE Pulp and Paper Industry Subcommittee Conference will be held in Kalamazoo, Mich., during the month of June, 1961. Kalamazoo has approximately 80,000 population and is the home of Western Michigan University.

## *14th Alkaline Pulping Conference*

The TAPPI 14th Alkaline Pulping Conference will be held Aug. 22–24, 1960, at the Hotel Multnomah, Portland, Ore. The local arrangements committee is comprised as follows:

Chairman: A. H. Wickett, Weyerhaeuser Timber Co. Longview, Wash.
Conference Arrangements: R. P. Shanaman, Pennsalt Chemicals Corp. of Washington, Tacoma, Wash., assisted by Roy Diefenbach.
Hospitality: Frank Lemma, assisted by Hoke Martin and Milton Maguire.
Registration: Robert Baer, assisted by James McCulloch.
Housing: J. L. McClintock, Weyerhaeuser Timber Co., Longview, Wash., assisted by Gordon Petrie.
Printing: Sidney Drew, assisted by Robert Smythe.
Transportation: Douglas Armstrong, assisted by Thomas King.
Mill Visits: R. E. Morris, Crown Zellerbach Corp., Camas, Wash., assisted by Jack Wilcox and Roy Shanaman.
Ladies' Program: Frank Caskey, assisted by H. B. Peterson.

The conference schedule is as follows:

**Committee Meetings**

**SUNDAY, Aug. 21, 1960**

***10:00 a.m.*** ***Local Arrangements***
***2:00 p.m.*** ***Alkaline Pulping***

**MONDAY, Aug. 22, 1960**

***4:30 p.m.*** ***Sulfite Pulping***

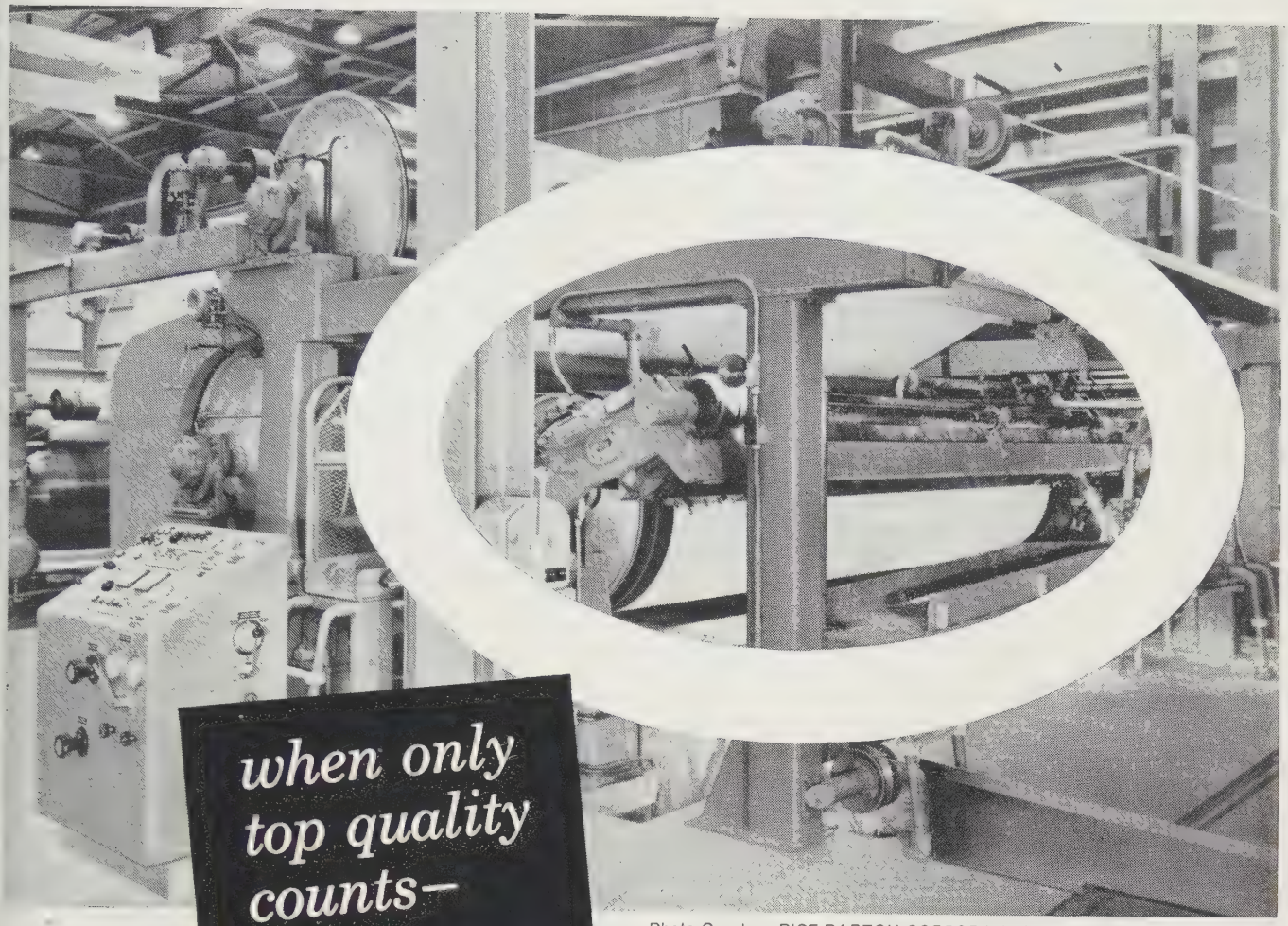
### TENTATIVE TECHNICAL PROGRAM

**MONDAY, AUG. 22, 1960**

*Morning Session:* Alkaline Pulping Session I

*Moderator*—D. Wetherhorn, Continental Can Co., Inc.

1. "An Evaluation of Certain Laboratory Pulping Methods," Edward F. Thode, John R. Peckham, and Edward J. Daleski, The Institute of Paper Chemistry.
2. "The Effects of Outside Storage on Slash Pine Chips in the South," C. W. Rothrock, St. Regis Paper Co., W. R. Smith, Southeastern Forest Experiment Station, and R. M. Lindgren, U. S. Forest Products Laboratory.
3. A paper on the Impco Continuous Digester at Hammermill (Erie) will probably be co-authored by supplier and mill.
4. "Diagnosis of Deposits of Pulp Mill Origin," R. T. Mashburn, P. D. Applegate, and H. R. Miller, Hercules Powder Co.
5. "Abatement of Air and Water Pollution," Vinton W. Bacon, Northwest Pulp & Paper Association.

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# CLINTON CORN STARCHES

for TRAILING BLADE COATING

## CLINCO OXIDIZED STARCHES

Today's high-speed coating techniques call for color formulations with high solids and high viscosities. To meet these needs, CLINTON recommends CLINCO Oxidized Starches which offer a marked increase in ink "holdout", greater uniformity of coating on the sheet and better acceptance of the coated surface for printing inks. The next time you make a formulation for use in the trailing blade coater, find out what CLINCO 330-B, CLINCO 314-B, and CLINCO 55 can do for *you!*

**TECHNICAL SERVICE**
on specific problems is yours on request.
We'd like to be of service. Just write.

CLINTON

**CLINTON CORN PROCESSING COMPANY, CLINTON, IOWA**

*Afternoon Session:* Alkaline Pulping Session II

*Moderator*—K. M. Shold, Crown-Zellerbach Corp.

1. "A Modern Design for Kraft Recovery Dissolving Tanks," C. R. P. Cash.
2. "Interaction of Smelt and Water," H. P. Markant, C. E. Rogers, and H. Dluehosh, Babcock & Wilcox Co.
3. "Experiences with the Production of Chlorine Dioxide," Thomas C. Payne and Billy Wade Smith, International Paper Co.
4. "Operational Experiences with Continuous Calcium Hypochlorite Systems," John W. Klein, Longview Fibre Co., and Harry S. Fisher, Pennsalt Chemicals Corp.

**TUESDAY, AUG. 23, 1960**

*Morning Session:* Alkaline Pulping Session III

*Moderator*—Eric S. Rice, St. Regis Paper Co.

"Panel Discussion on High Yield Kraft Pulping." Panel to be composed of mill men representing mills in the South, Southeast, West Coast, and Canada.

*Afternoon Session:* Sulfite Pulping Session

Semichem portion of program. Four papers to be presented.

*Mill Visits* are being planned with trips to Crown Zellerbach Corp., Camas, Wash.; Longview Fibre Co., Longview, Wash.; Weyerhaeuser Timber Co., Longview, Wash.; the Electric Steel Foundry, Portland, Ore.; and Pennsalt Chemical Co., Portland, Ore.

A woods trip is also being arranged with details to be announced later.

An interesting ladies' program is being planned with one feature being a trip to Timberline Lodge on Mt. Rainier.

There will be preregistration which will include housing arrangements. It is suggested those planning to attend the conference complete promptly the form below and return it with your check to J. L. McClintock, Weyerhaeuser Timber Co., Longview, Wash. Please make checks payable to "TAPPI Conferences—T." Your registration fee must accompany the form to insure housing reservations.

## *11th Testing Conference*

The 11th Annual Testing Conference sponsored by the Technical Association of the Pulp and Paper Industry will be held Sept. 27–29, 1960, at the Pantlind Hotel, Grand Rapids, Mich.

W. R. Willets, Program Chairman, has announced a symposium on the testing of "Water—the Most Important Nonfibrous Raw Material." E. W. Petrich, Howard Paper Mills, Inc., Urbana, Ohio, will be the moderator. The following papers will be presented:

"Process Water," by R. K. Bamman, Champion Paper & Fibre Co., Hamilton, Ohio
"Waste Water," by W. A. Flower, Howard Paper Mills, Inc., Urbana, Ohio
"Boiler Water," by M. H. Borland, Chillicothe Div., Mead Corp., Chillicothe, Ohio

The General Session will consist of the following papers:

"Factors Influencing Testing of Gummed Tape," by Ernest Werle, Darling & Co., 4201 South Ashland Ave., Chicago, Ill.
"A Comparison of Proposed Test Methods for Measuring the Adhesive Strength of Casein and Isolated Soy Protein in a Pigmented Coating," by L. E. Georgevits and W. L. Marino, The Borden Chemical Co., Bainbridge, N. Y.
"Survey of Sampling and Precision Requirements in Present TAPPI Test Methods," by Charles A. Bicking, The Carborundum Co., P. O. Box 337, Niagara Falls, N. Y.
"Measurement of Fiber Flexibility," by A. A. Robertson, E. Meindersma, and S. G. Mason, Physical Chemistry Div., Pulp and Paper Research Institute of Canada, Montreal, Que.

To be presented by title:

"Identification of Coniferous Woods," by B. F. Kukachka, Forest Products Laboratory, Madison, Wis.
"Development of Dirt Contribution Factors for Dirt in Pulpwood Chips," by Edwin Birkhimer, T. C. Rowland, H. B. Stanos, B. E. Lauer, Dept. of Chemical Engineering, Univ. of Colorado, Boulder, Colo.

T. W. Lashof, National Bureau of Standards, Washington, D. C., is chairman of the relative humidity symposium "Relative Humidity and Paper Test Methods."

The physical properties of paper change appreciably for quite small changes in relative humidity. Present standards for the testing of paper call for a conditioning and testing room to be controlled to 50 ± 2% relative humidity and 23 ± 2°C. Some feel that even these narrow limits will result in significant variations in the measured properties of the paper.

Because of the serious difficulties encountered in controlling and measuring the relative humidity of a test room to such narrow limits as are now specified for paper, and the possibility that even narrower limits are required, ASTM Committee D-6 on Paper and Paper Products and the TAPPI Testing Division are jointly sponsoring the symposium on this subject.

The tentative program for the symposium is given below.

W. E. Bennett, Research Physicist, and Miss D. M. Crook, British Paper & Board Industry Research Association: "Effect of Relative Humidity on Some Physical Properties of Paper."

Miss G. A. Bernier, group leader, Statistical Services, and W. E. Carlson, manager of Central Research, St. Regis Paper Co. "The Effect of Relative Humidity on the Stress-Strain Properties of Kraft Multiwall Paper."

W. Brecht, professor dr.-ing., Institut für Papierfabrikation, Technische Hochschule Darmstadt: "Reasons for 65% R.H. and 20°C., and Other Topics."

Willmer A. Wink, chief, Paper Evaluation Section, The Institute of Paper Chemistry: "Effect of Relative Humidity on the Evaluation of Paper Properties."

A. C. Poulter, B.Sc., Group Research Department, Research and Development Division, Albert E. Reed & Co., Ltd.: "Some Developments in the Measurement of Relative Humidity."

Arnold Wexler, research engineer in charge of Humidity Standards Laboratory, National Bureau of Standards: "Standards in the Measurement of Relative Humidity."

J. A. Cairns, The Printing, Packaging & Allied Trades Research Association: "The Design and Control of Test Rooms and Small Ovens."

L. L. Clapp, process and production development engineer, Technical Div., St. Regis Paper Co.: "A Conditioning Room in Which a Great Deal of In and Out Traffic Does Not Upset Conditions; a Rapid Conditioner."

Frank M. Gavan, chairman ASTM Committee E-1, Sub. 14, on Conditioning and Weathering, and Manager, Physical Test Department, Armstrong Cork Co. "The Constant Temperature Room as a Testing Facility: Its Design and Construction from a User's Viewpoint."

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**Tenth**

**Corrugated Containers**

**Conference**

**Royal York Hotel**

**Toronto, Ont.**

**Oct. 10–13, 1960**

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# TAPPI NOTES

## *TAPPI Career Guidance Activities*

One of the six objects of the Technical Association of the Pulp and Paper Industry is "to promote education in the science and practice of pulp and paper manufacture." Consistent with this object, the association has a responsibility to attract high-caliber technical personnel for employment in the pulp and paper field, and to provide guidance and counsel to students and technologists who may be interested in a career in this field.

This responsibility has been recognized by the TAPPI Executive Committee in the authorization of several career guidance activities:

1. A speakers program for student groups.
2. A booklet to attract science and engineering students to the industry.
3. Participation in the Paper Industry Career Guidance Committee.

The Technical Operations Committee recommended in 1958 that TAPPI headquarters coordinate a program to provide speakers to acquaint science and engineering students with the pulp and paper industry and its career potential. P. E. Nethercut and J. W. Field, TAPPI, New York, N. Y., assembled kits of materials for speakers, and carried the program forward by arranging for TAPPI members to address student chapters of the American Chemical Society, the American Institute of Chemical Engineers, and the American Society of Mechanical Engineers at nearby colleges and universities throughout the country.

More than 70 talks have been given by TAPPI members and headquarters' staff. Since the program is possible only with the cooperation of TAPPI members and their employers, its success to date indicates that this cooperation has been freely given by both. It is planned as a continuing program that will achieve its fullest effect only after several years of operation.

In 1958 a subcommittee of the Technical Operations Committee under W. H. Aiken, Personal Products Corp., Milltown, N. J., recommended that TAPPI produce and distribute a brochure describing career opportunities in the industry, aimed specifically at senior students in science and engineering. In February, 1959, the Executive Committee authorized this program and President J. R. Lientz appointed H. O. Ware, Beveridge Paper Co., Indianapolis, Ind., and A. J. Winchester, TAPPI, New York, N. Y., as a subcommittee to carry the project forward.

The firm of Fuller-Miele, Inc., New York, N. Y., was engaged to produce the brochure, which was completed in December, 1959.

Initial distribution to colleges, universities, pulp and paper and allied companies has resulted in the following requests and orders:

| | |
|---|---|
| 828 Paper and allied companies | 11,093 copies |
| 321 Schools and colleges | 1,325 copies |
| 138 Individuals | 141 copies |
| 24 Government agencies | 2,723 copies |

The brochure is being sold to paper and allied companies for recruiting purposes, and the back cover was left blank to permit imprinting company identification.

The brochure highlights several of the many facets of the technical work done by pulp and paper companies and allied organizations. This is accomplished with a number of definitive articles prepared by industry leaders, government agencies, major paper users and other organizations directly and indirectly concerned with research and uses of paper and paper products.

The booklet also presents a background history of the industry and its growth, a projection of future potential, and a detailed analysis of the specific types of career opportunities open to graduates with science and engineering degrees.

Early in 1959, W. Chisholm, president of Oxford Paper Co. and chairman of the Public Relations Committee of the American Paper & Pulp Association, suggested the formation of an intersociety career guidance committee. TAPPI President J. R. Lientz appointed H. O. Ware and A. J. Winchester as the TAPPI representatives to this committee, and within a short time the committee included representatives from Paper Industry Management Association, National Paperboard Association, and National Paper Trade Association as well as APPA and TAPPI. Later in the year Mr. Ware resigned from the committee and R. T. Trelfa, Perkins-Goodwin Co., New York, N. Y., was appointed to succeed him.

The committee has undertaken a survey of the industry to determine its specific needs for trained personnel in all fields. This information will be used to draft a comprehensive career guidance program for the industry as a whole, to be coordinated by the committee as a cooperative effort of the five participating associations.

Recognizing an immediate need for guidance material at the high-school level, the committee has produced an informative booklet designed to stimulate students to consider the pulp and paper field for their future careers. The 24-page booklet gives descriptions of the kinds of jobs offered by the industry, lists scholarships available from paper and allied companies, and names universities where training in pulp and paper technology may be obtained.

The long-range plans of the committee may include teachers kits, pamphlets, booklets, films, speakers' programs, exhibits, and other career guidance devices for use at all levels where it is felt that beneficial results may be achieved.

A. J. Winchester

# PERSONAL MENTION

## *New TAPPI Members*

*Ikuo Adachi*, Sales Engineer, Ataka & Co., Ltd., Tokyo, Japan. Attended Tokyo Institute of Technology.

*John S. Apperson*, Application Specialist, General Electric Co., Charlotte, N. C., a 1940 graduate of Virginia Polytechnic Institute.

*Walter B. Bergstrom*, Sales Engineer, Babcock & Wilson Co., Chicago, Ill.

*Lowell Besley*, Chairman, Woodlands Research Dept., Pulp and Paper Research Institute of Canada, Montreal, P. Q., Canada, a 1931 graduate of Cornell University.

*Ernest Beyers*, Principal Technical Officer, South African Bureau of Standards, Pretoria, South Africa, a 1927 graduate of University Stellenbosch with a D.Sc. degree in 1935.

*Fred Borders*, Superintendent, Loy-Lange Box Co., St. Louis, Mo. Attended Ohio State University.

*Herman P. Briar*, Research Chemist, James River Div., Dow Chemical Co., Williamsburg, Va., a 1951 graduate of University of California.

*Andrew A. Broz*, Technical Director, Pulp & Paperboard Div., Weyerhaeuser Co., Everett, Wash., a 1949 graduate of University of Washington.

*Henry A. Buckley*, Production Manager, Standard Paper Box Mfg., Ltd., Montreal, Canada, a 1928 graduate of Montreal College.

*Robert T. Callahan*, Technical Service Representative, St. Regis Paper Co., Chicago, Ill., a 1946 graduate of College of Holy Cross.

*Jan W. Cappelen*, Director General, The Kellner-Partington Paper Pulp Co., Ltd., Hallein, Salzburg, Austria. Attended Uppsala University.

*Ramiro Careaga*, Process Engineer, Davidson-Kennedy Associates Co., Chicago Heights, Ill., a 1952 graduate of Brooklyn Polytechnic Institute.

*Charles L. Carns*, Construction Engineer, Pulp & Paperboard Div., Weyerhaeuser Co., Longview, Wash., a 1944 graduate of University of Iowa.

*Alexander J. Castle*, Manager, Kaiser Aluminum & Chemical Sales, Inc., Chicago, Ill., a 1951 graduate of Carnegie Institute of Technology.

*James F. Connelly*, Chemist, International Business Machine Corp., Binghamton, N. Y., a 1955 graduate of College of Forestry, State College of New York.

*Lewis B. Connelly*, Sales Representative, Eastman Chemical Products, Inc., Kingsport, Tenn., a 1948 graduate of Virginia Polytechnic Institute.

*Alfonso Corb-Colombo*, Branch Manager, NYMCO S.p.A., Milano, Italy.

*Conrad F. Cornell*, Development Engineer, The Eimco Corp., Palatine, Ill., a 1954 graduate of Northwestern University.

*Aldo Corvaja*, Consulting Engineer, Milan, Italy, a 1929 graduate of Instituto Feltrinelli.

*LeRoy E. De Marsh*, Production Engineering Supervisor, General Box Co., Des Plaines, Ill., a 1953 graduate of Michigan State University.

*A. Edward Dembitz*, Chief Civil Engineer, Singmaster & Breyer, Inc., New York City, N. Y., a 1935 graduate of Rensselaer Polytechnic Institute.

*Edward C. Denne, Jr.*, Assistant Chief Engineer, S.K.F. Industries, Inc., Philadelphia, Pa., a 1948 graduate of Carnegie Institute of Technology.

*Arthur V. Dupuis*, Project Leader, Food Machinery and Chemical Corp., Baltimore, Md., a 1951 graduate of Northwestern University.

*Marco L. Eva*, Manager, Cartiera Pirinoli S.p.A., Torino, Italy, a 1956 graduate of the Polytechnic University.

*Charles J. Fisher*, Plant Manager, Wyomissing Paper Products Div., Narrow Fabric Co., Reading, Pa., a 1946 graduate of Massachusetts Institute of Technology.

*Robert M. Fletcher*, Technical Service Engineer, S. D. Warren Paper Co., Cumberland Mills, Me., a 1956 graduate of University of Maine.

*Richard J. Fink*, Senior Project Engineer, Permacel Div., Johnson & Johnson, North Brunswick, N. J., a 1958 graduate of Columbia University.

*Giovanni B. Franceschini*, Production Director, Cartiera di San Cesario, Milano, Italy, a 1948 graduate of University of Padua.

*Edwin Fuhrlbeck*, Assistant Technical Manager, ER-WE-PA G.m.b.H., Dusseldorf, Germany, a 1958 graduate of Darmstadt University with a Ph.D. degree.

*Shinichi Eukuma*, Technical Advisor, Mitsubishi Shipbuilding & Engineering Co., Ltd., Tokyo, Japan, a 1928 graduate of Hiroshima Technical University.

*Edward C. Garver, Jr.*, Manager, Chemical Intermediates, Armour Industrial Chemical Co., Chicago, Ill., attended Drexel Institute of Technology.

*Albert A. Goodrow*, Research Chemist, Ludlow Papers, Inc., Needham Heights, Mass., a 1951 graduate of Boston College.

*C. George Green*, Technologist, Shell Chemical Co., New York, N. Y., a 1950 graduate of University of Delaware.

*Gary E. Greene*, Chemist, Fibrocast Div., Firestone Tire and Rubber Co., Magnolia, Ark., a 1957 graduate of Southern State College.

*David N. Greey*, Vice-President, Greey Mixing Equipment, Ltd., Toronto, Ont., Canada, a 1950 graduate of University of Toronto.

*Robert Gresl*, Manager, Project Engineering, Permacel Div., Johnson & Johnson, New Brunswick, N. J., a 1949 graduate of Columbia University.

*John J. M. Halbig*, Senior Research Engineer, Armco Steel Corp., Middletown, Ohio, a 1940 graduate of Johns Hopkins University.

*Patrick J. Hargon*, Chemist, Hamilton Manufacturing Co., Richmond, Va. Attended Richmond Professional Institute.

*Hiroshi Hayashi*, Chemical Engineer, Toyo Roshi Kaisya, Utsunomiyashi-Shi, Japan, a 1948 graduate of Tohoku University.

*Stewart K. Henry*, Control Superintendent, International Fibre Board, Ltd., Gatineau, P. Q., Canada, a 1954 graduate of Mount Allison University.

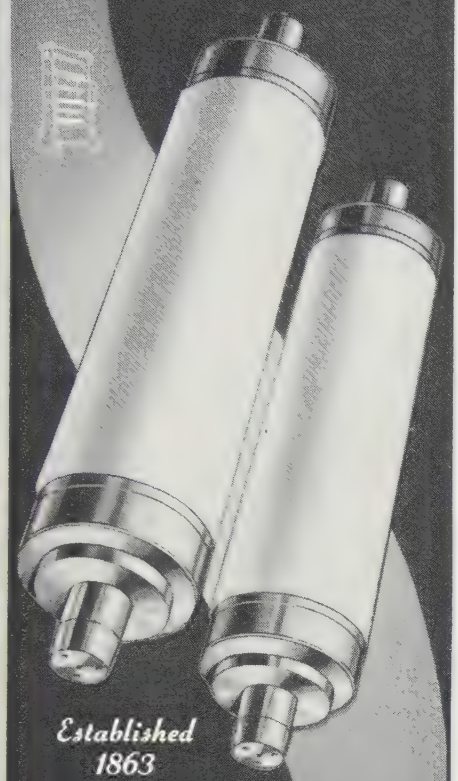
*Thomas F. Herron*, Senior Project Engineer, Permacel Div., Johnson & Johnson, New Brunswick, N. J., a 1951 graduate of Drexel Institute.

*Richard N. Hess*, Assistant Soda Mill & Deinking Supervisor, New York and Pennsylvania Co., Lock Haven, Pa., a 1953 graduate of College of Forestry, State College of New York.

*John C. Hintermaier*, Manager, Physical Research, Huyck Felt Co., Rensselaer, N. Y., a 1934 graduate of Philadelphia Textile School.

*Hans-Joachim Hofmann*, Chief Chemist, Hamburger Mineralol-Werke Ernst Jung, Hamburg, Germany, a 1936 graduate of Technical University, Munchen, with a D.Ing. degree.

# "HOLYOKE" CALENDER ROLLS



*Established 1863*

**For nearly a century** "HOLYOKE" Rolls have been world renowned for sturdy, rugged construction, designed to give dependable, long life.

We are equipped to give service on new and refilled rolls with various types of fillings and densities. Also stainless steel, steel, brass and special purpose rolls.

Our engineers will gladly call to give you the benefit of their long experience making rolls for processing textiles and paper.

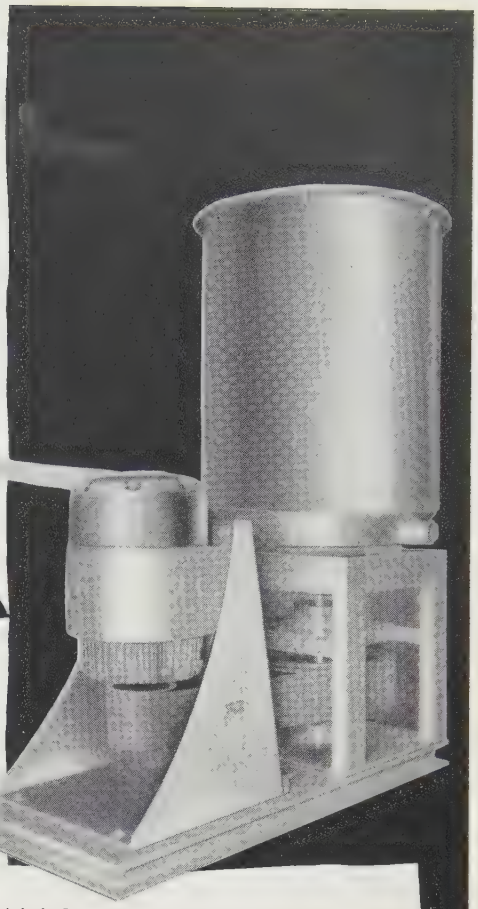
*Correspondence Invited*

## HOLYOKE MACHINE COMPANY

CALENDER and EMBOSSING ROLLS
for the PAPER and TEXTILE INDUSTRIES
WATER FILTRATION EQUIPMENT
HOLYOKE, MASSACHUSETTS

# FOR ALL PAPER COATINGS

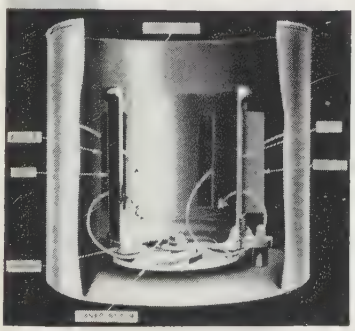
*TO ANY DESIRED SOLIDS CONTENT*



## abbé DISPERSALL MIXER

■ The versatile Abbé Dispersall Mixer is equally effective on all types of coatings; low or high solids. The Dispersall Mixer produces a consistent, completely dispersed coating quickly and efficiently.

■ In use for more than 20 years by the paper industry, the Dispersall Mixer has kept pace with the technological advances of paper coatings and the demands of modern production. The increasing number of trailing blade systems being installed today has made the employment of the modern Dispersall Mixer in the coating department more important than ever.



*Abbé Dispersall Mixer for Thin to Heavy Slurries*

■ Whether you coat bleached board or paper, and regardless of the coating system used, the Dispersall Mixer will be of interest to you.

■ From Florida to Finland, paper and board coatings are being made faster and better in the Dispersall. Write today . . . we are eager to tell our story on how the Dispersall Mixer can serve you.

## abbe' ENGINEERING COMPANY

620 S Graybar Bldg., New York 17, N. Y.

Designers and Manufacturers of
Ball, Pebble and Jar Mills • Pulverizers • Sifters • Cutters • Mixers

*Charles Holckner,* General Manager, General Paper Mills Pty., Ltd., Melbourne, Australia. Attended Melbourne Technical College.

*Francis E. Horan,* Group Leader, Archer-Daniels-Midland, Minneapolis, Minn., a 1945 graduate of Columbia University with a Ph.D. degree.

*Yusaka Itagzki,* Technical Engineer, Chuetsu Machine Co., Ltd., Toyama-Pref., Japan, a 1957 graduate of Iwate University.

*Paul K. Jackson,* Physical Testing, E. I. du Pont de Nemours & Co., Newport, Del. Attended Colgate University.

*Lennart A. Janson-Herminge,* Head, Research Dept., Central Laboratory of the Swedish Paper Mills, Stockholm, Sweden, a 1954 graduate of University of Uppsala.

*Thomas R. C. Jeffries,* Sales Representative, Northeastern Paper Sales, Inc., Chicago, Ill., a 1956 graduate of Rutgers University.

*Adolph P. Johnson,* Sales Representative, Archer-Daniels-Midland Co., Chicago, Ill. Attended Concordia College.

*Robert K. Jones,* Staff Engineer, Johns-Manville Corp., New York, N. Y., a 1950 graduate of City College of New York.

*W. Britton Jordan,* Sales Engineer, The Foxboro Co., Minneapolis, Minn., a 1948 graduate of University of Minnesota.

*Lawrence M. Joseph,* Production Manager, Gemayel Freres, Beirut, Lebanon. Attended Ecole Française de Papeterie, Grenoble.

*Robert A. Joss,* Assistant Executive Secretary, Technical Section, Canadian Pulp & Paper Association, Montreal, P. Q., Canada, a 1950 graduate of McGill University.

*Lennart N. Johanson,* Associate Professor, University of Washington, Seattle, Wash., a 1942 Graduate of University of Utah with a Ph.D. degree in 1948.

*Richard N. Kesner,* Vice-President, Bennett, Inc., Cambridge, Mass. Attended University of Chicago.

*Herbert Kramer,* Technical Advisor, Permacel Div., Johnson & Johnson, New Brunswick, N. J., a 1948 graduate of Newark College of Engineering.

*Joseph M. Laverie,* Assistant Chief Chemist, Michael Nairn & Co., Ltd., Fife, Scotland, a 1938 graduate of Glasgow University with a Ph.D. degree in 1949.

*Marion E. Leary,* Librarian, Forestry Commission, Sydney, Australia.

*Arno Lessheim,* Project Engineer, Aillenbrand Industries, Batesville, Ind.

*Robert A. Lindquist,* Sales Engineer, Atlantic Bearings Corp., Cambridge, Mass., a 1951 graduate of Massachusetts Institute of Technology.

*M. Matsumoto,* Vice-Director of Research Laboratories, Kurashiki Rayon Co., Ltd., Okayama Pref., Japan, a 1940 graduate of Kyoto University with a Ph.D. degree in 1950.

*Robert D. McDaid,* Quality Control Engineer, St. Joe Paper Co., Hartford City, Ind., a 1957 graduate of Michigan State University.

*H. Chester McLaughlin,* Supervisor Quality Control, New York & Pennsylvania Co., Inc., Lock Haven, Pa., a 1935 graduate of Pennsylvania State University.

*Ralph B. Miller,* Sales Service Representative, Corn Products Sales Co., New York, N. Y., a 1933 graduate of Tufts College.

*Garrett C. Mitchell, Jr.,* Maintenance Superintendent, New York & Pennsylvania Co., Inc., Lock Haven, Pa., a 1948 graduate of Pennsylvania State University.

*Edward L. Morehouse,* Chemist, Silicones Div., Union Carbide Corp., Tonawanda, N. Y., a 1942 graduate of University of Michigan.

*Osamu Morita,* Assistant Manager, Kure Branch of Hitachi Works, Hitachi, Ltd., Hiroshima-ken, Japan, a 1930 graduate of Tokyo University.

*Peter C. Muffat,* Research Chemist, Ecusta Div., Olin Mathieson Chemical Corp., Pisgah Forest, N. C., a 1938 graduate of University of Wuerzburg, Germany.

*John P. Munton,* Chief Engineer, Rice Barton Corp., Worcester, Mass., a 1934 graduate of University of New Hampshire.

*A. Okamoto,* Chief, Rayon Manufactural Section, Kurashiki Rayon Co., Ltd., Okayama Pref., Japan, a 1926 graduate of Kyoto University.

*Fritz Opderbeck,* Technical Director, Phrix-Werke A.G., Frankfurt, Germany.

*Joseph A. Orsino,* Technical Director, National Lead Co. Research Laboratories, Brooklyn, N. Y., a 1933 graduate of Ohio State University.

*W. S. Osgood,* Vice-President and General Manager, Valentine Pulp & Paper Co., Lockport, La., a 1939 graduate of State University of Iowa.

*Walter C. Ost,* Corrugator Supervisor, Mead Containers, North Bergan, N. J.

*Peter R. O'Sullivan,* Application Engineer, Westinghouse Electric International Co., New York, N. Y., a 1952 graduate of Stevens Institute of Technology.

*Michael L. Papesh,* Division Sales Manager, Beloit Iron Works, Beloit, Wis.

*James B. Papoe,* Assistant Mill Manager, Abitibi Power & Paper Co., Ltd., Iroquois Falls, Ont., Canada, a 1945 graduate of University of Saskatchewan.

*Fredy A. Pesserl,* Plant Director, Cia. Industrial Commercial del Sur S.A., Montevideo, Uruguay.

*Thomas M. Quinn,* Salesman, Nitrogen Div., Allied Chemical Corp., New York, N. Y., a 1951 graduate of Boston College.

*Robert C. Ranew,* Engineer, J. E. Sirrine Co., Greenville, S. C., a 1957 graduate of Georgia Institute of Technology.

*Hubert O. Ranger,* Packaging Laboratory Director, General Foods Corp., Tarrytown, N. Y., a 1948 graduate of University of Maine.

*Kenneth E. Rauerbuhler,* Engineering Supervisor, The Mead Corp., North Bergen, N. J.

*Ian M. Reed,* Technical Director, Guardian Paper Co., Newark, Calif., a 1950 graduate of Melbourne Technical Institute.

*Harry F. Reid, Jr.,* Manager, Technical Service, The McKay Co., York, Pa., a 1939 graduate of Geneva College

*Ellwood J. Rice,* Technical Service Representative, Hercules Powder Co., Holyoke, Mass., a 1954 graduate of McGill University.

*Leslie E. Richard,* Research Chemist, Plastic Coating Corp., Holyoke, Mass., a 1951 graduate of Dartmouth College.

*David B. Robinson,* Development Superintendent, Diamond National Corp., Plattsburgh, N. Y., a 1950 graduate of Utah State Agricultural College.

*Oliver E. Rodgers,* Manager of Mechanical Research, Scott Paper Co., Chester, Pa., a 1936 graduate of Harvard University.

*Helmut Roederer,* Chemist, Deutsche Maizena Werke GMBH, Hamburg, Germany.

*Zenon F. Rozycki,* Technical Director, Manistique Pulp & Paper Co., Manistique, Mich., a 1939 graduate of University of Poznan, Poland.

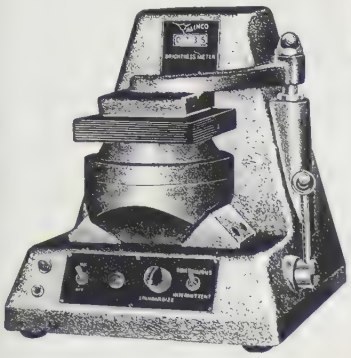
*Wilhelm Sandermann,* Director, Institute for Wood Chemistry, Federal Research Laboratory for Forestry & Forest Products, Hamburg, Germany.

*Eldon L. Saul,* Technical Services Representative, Continental Oil Co., Houston, Texas, a 1950 graduate of Texas Technological College.

*James F. Sauvage,* Technical Representative, Union Carbide Chemical Co., New York, N. Y., a 1954 graduate of Trinity College, with a Ph.D. degree in 1960, from Northwestern University.

*Richard Lee Schmalz,* Patent Agent Trainee, West Virginia Pulp & Paper Co., Luke, Md., a 1957 graduate of Centre College of Kentucky.

Another of a series of files of precision products by ALINCO



Accuracy, Standardization and Speed—ALINCO

# BRIGHTNESS METER—Model 50

- SIMPLIFIED OPERATION
- STANDARDIZED READINGS
- COMPACT — LOW COST

Specially designed for use in the paper industry, this ALINCO Brightness Meter provides accurate, standardized and rapid brightness measurements. Its rugged construction and the rapidity of its readings make it particularly attractive in those plants where a great many readings are necessary. Measuring the brightness of larger areas than other commercially available instruments, the ALINCO Brightness Meter, therefore, renders readings statistically more accurate and reliable.

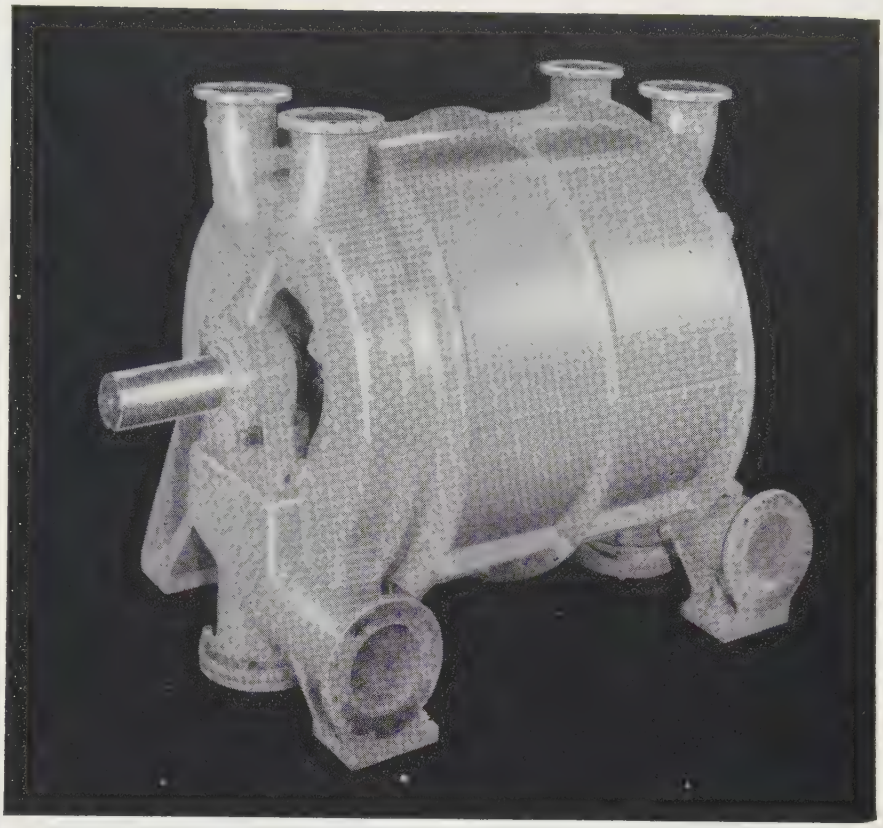
The meter is designed for operation by non-skilled personnel and incorporates special features which minimize chance for error. The reading is presented on a digital counter which eliminates interpretation by the non-skilled employee, removing the human error factor. The material to be tested is simply inserted and clamped and the reading is automatic.

For additional information on the Model 50 Brightness Meter or for the answer to your specific smoothness testing, gloss testing or bleach control problems, write:

ALINCO

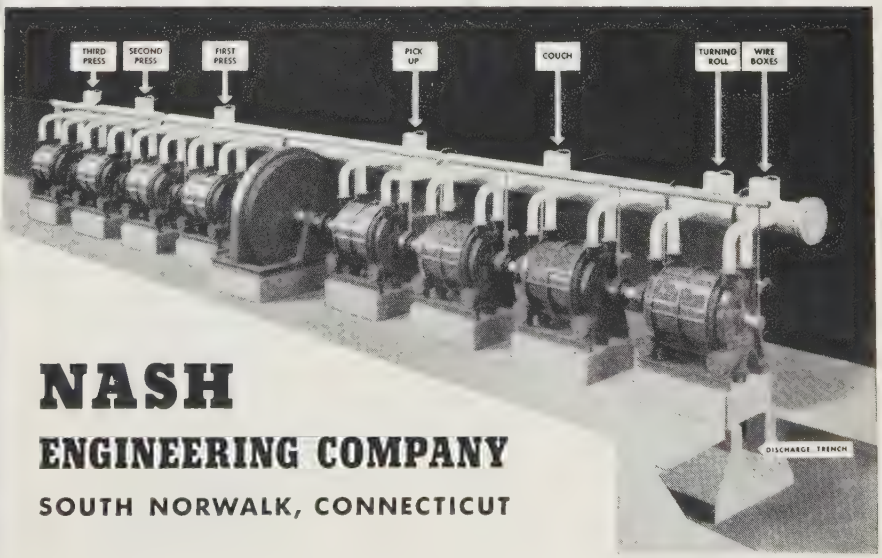
Allegany Instrument Company, Inc.
Cumberland, Maryland
Palo Alto, Calif. • Washington, D. C.

# This New Nash Vacuum Pump Offers Four Separate Suctions and Vacuums Simultaneously



The Nash 5308-A has four separate suction inlets, each of which functions independently of the others. This offers the machine operator great flexibility, since these may be used in any desired combination to produce a variety of capacities and vacuums.

Picture below shows simple drive possible and flexibility of piping permitting capacities to exactly fit requirements of different sections of the paper machine.




NASH
ENGINEERING COMPANY
SOUTH NORWALK, CONNECTICUT

*Peter J. Schwartz, Jr.*, Tour Boss, Continental Can Co., Piermont, N. Y., a 1954 graduate of Syracuse University.

*Alexander Shand*, Chemist, Dow Chemical Co., Midland, Mich., a 1950 graduate of Princeton University.

*Sidney Silverstone*, Chief Process Engineer, Scott Paper Co., Everett, Wash., a 1938 graduate of University of Washington.

*B. D. Somani*, Director, The West Coast Paper Mills, Ltd., Bombay, India.

*William D. Stitt*, Vice-President, Buckman Laboratories, Inc., Memphis, Tenn.

*W. Dick Stroud*, Division Sales Manager, Huyck Felt Co., Rensselaer, N. Y., a 1921 graduate of McGill University.

*Cornelius A. Sullivan*, General Foreman, Continental Can Co., Inc., Cleveland, Ohio.

*Harry Tecklenburg*, Director, Paper Products Development Dept., The Procter & Gamble Co., Cincinnati, Ohio, a 1950 graduate of Massachusetts Institute of Technology.

*Roger B. Thompson*, Process Engineer, Kalamazoo Vegetable Parchment Co., Kalamazoo, Mich., 1957 graduate of Michigan State University.

*William K. Thorndike*, Group Leader, S. D. Warren Co., Cumberland Mills, Me., a 1953 graduate of University of Maine.

*Carl H. Tildes*, Sales Manager, J. E. Rhoads & Sons, Wilmington, Del., a 1924 graduate of South Dakota States School of Mines & Technology.

*Yoshio Tsukada*, Instrumentation Engineer, Yamatake-Honeywell Keiki Co., Tokyo, Japan, a 1956 graduate of Nagoya University.

*Donald V. Walden*, Management Trainee, New York & Pennsylvania Co., Inc., Lock Haven, Pa., a 1958 graduate of Pennsylvania State University.

*Frederick C. Walker*, Mill Manager, Price Bros. & Co., Ltd., Quebec, P. Q., Canada.

*Donald D. Wangerin*, Sales Engineer, Combustion Engineering, Inc., New York, N. Y., a 1949 graduate of New York University.

*Bradford B. Waterman II*, Manager, Medway Div., United Shoe Machinery Corp., West Medway, Mass.

*William E. Winans, Jr.*, Applied Science Representative, International Business Machine Corp., Green Bay, Wis., a 1949 graduate of Grinnell College.

*F. A. Wolfrum*, The Laboratory, United Empire Box Co., Ltd., Frankton, New Zealand

## *Appointments*

*Joseph Abelson*, formerly of Hamilton Paper Co., is now a Chemist for Arnold, Hoffman & Co., in Providence, R. I.

*Russell L. Adams*, formerly of Hudson Pulp & Paper Co., is now Technical Director of Burrows-Mohawk Corp., Little Falls, N. Y.

*George A. Aljian*, Vice-President of California & Hawaiian Sugar Refining Corp., has retired.

*Norman Alper* is now Vice-President of the Pulp and Paper Division of Cavedon Chemical Co., Inc. Woonsocket, R. I.

*Alex Berzins*, formerly of Papeterie de la Seine, is now Manager of Zellstofffabrik Waldhoff, Weisbaden, W. Germany.

*Francis O. Boylon* is now Vice-President in Charge of Manufacturing of the Crown Zellerbach Corp., San Francisco, Calif.

*Clive H. Bubb*, formerly of the Dixie Cup Co., is now a Process Chemist for Diamond National Co., Palmer, Mass.

*Corwin S. Burghardt*, formerly of the Calcesieu Paper Co., is now a Forest Engineer for the Container Corp. of America, Fernandina Beach, Fla.

*Wm. W. Y. Chou* is now Chief Engineer of Taiwan Pulp & Paper Corp., Hsinying, Formosa, China.

*Harry G. Davis*, formerly of Tube Turns Plastics, Inc., is now Manager of the Chemical Fine Paper & Board Division Standard Packaging Corp., Holyoke, Mass.

*Harold V. Dearden*, formerly of Inveresk Paper Co., Ltd. is now an Engineer with Millspaugh, Ltd., Sheffield, England

*Theodore E. Detcher*, formerly of John W. Rouse Construction Corp., is now Assistant Sales Manager of the Pandia Division of Black-Clawson Co., Middletown, Ohio.

*Robert T. Elias*, formerly of the Racquette River Paper Co. is now Director of Research for the Bondware Division of Continental Can Co., Chicago, Ill.

*Saxton W. Fletcher*, President of the J. O. Ross Engineering Division of Midland-Ross Corp., has retired.

*Valentine Friedrich, Jr.*, formerly of the Beckett Paper Co. is now Division Manager of the Watervliet Paper Co., Watervliet, Mich.

*William H. Friend*, formerly of Diamond National Co., is now a Chemical Engineer for Personal Products Corp. Milltown, N. J.

*Angus J. Gardner*, formerly of Rice Barton Corp., is now Vice-President and Director of Marketing for the Packaging Division of Olin Mathieson Chemical Corp., New York, N. Y.

*Warren A. Girard*, formerly of Grace Paper Co., is now Mill Manager of Papeles Grace Colombiance S/A, Cali, Columbia

*Charles C. Goodwin*, formerly Instructor at the University of Maine, is now a Chemical Engineer for the Riegel Paper Corp., Milford, N. J.

*Edgar B. Gutoff*, formerly of Ionics, Inc., is now a Senior Engineer for Polaroid Corp., Waltham, Mass.

*Frank D. Hall*, formerly of Container Corp. of America, is now a Technical Service Engineer for St. Regis Paper Co. Pensacola, Fla.

*William C. Hayes* is now Mill Manager of Owens-Illinois Glass Co., Valdosta, Ga.

*Jimmie L. Hillman*, Sales Engineer for the American Cyanamid Co., has been transferred from Kalamazoo, Mich. to Portland, Ore.

*Harry Huebert*, formerly of Fibreboard Mfg., Ltd., is now General Manager of Huebert Fibreboard Inc., Boonville, Mo.

*Otto V. Ingruber*, formerly of the Pulp & Paper Research Institute of Canada, is now a Science Associate with Industrial Cellulose Research, Ltd., Hawkesbury, Ont., Canada.

*Herbert F. Jacques*, formerly of Finch, Pruyn & Co., is now a Technical Engineer for St. Regis Paper Co., Carthage, N. Y.

*John G. Kauffman* is now Assistant Manager of the Michigan Division of Hamilton Paper Co., Plainwell, Mich.

*William D. Kenney*, formerly of Ace Carton Co., is now a Packaging Engineer for the Weyerhaeuser Timber Co., Chicago, Ill.

*Mark B. Koerner*, formerly of Owens-Illinois Fiberglas Co., is now Technical Director of Chase-Foster Inc., Providence, R. I.

*Wilbert M. Lair*, formerly of Wrenn Paper Co., is now Director of Research and Development for Continental Diamond Fibre Corp., Newark, Del.

*Herman Levin*, formerly of Pusey & Jones Corp., is now a Field Engineer for the Patton Manufacturing Co., Springfield, Ohio.

*Robert W. Long*, formerly of the Pulp & Paper Trading Co., is now a Project Engineer for the Packaging Corp. of America, Evanston, Ill.

*Frederick E. Macy*, formerly of the Brown Co., is now a Technical Consultant for the Hubinger Co., Philadelphia, Pa.

*Raymond W. McCormick*, formerly of the Owens-Illinois, Mill Division is now General Superintendent of the Continental Can Co., Augusta, Ga.

*Edgar A. McGinnis, Jr.*, formerly of the American Viscose Co., is now an Associate Professor in the School of Forestry, University of Missouri, Columbia, Mo.

*Harris C. Mersereau,* formerly of Canadian Industries, Ltd., is now an Engineer for Canadian Cellanese, Ltd., Montreal, Canada.

*Robert G. Mispley* is now Production Manager for the Crown Zellerbach Corp., San Francisco, Calif.

*Norman R. Moore, Jr.,* formerly of the Mohawk Paper Co., is now a Project Engineer for the Consolidated Paper Co., Monroe, Mich.

*Raoul L. Naville,* formerly of Pavag A/G., is now Manager of Papierfabrik Gemmrigheim, Wurtenburg, Germany.

*John J. Osmer,* formerly of Chicopee Mfg. Co., is now with Celanese Corp. of America, Charlotte, N. C.

*Richard R. Peck,* formerly of Southern Chemical Cotton Co., is now Technical Director for the Alpha Cellulose Corp., Bloomington, Ill.

*Leonard A. Pierce, Jr.,* formerly of the Penobscot Chemical Fibre Co., is now President of the Brown Co., Boston, Mass.

*Arthur W. Plummer* is now Assistant Vice-President and Director of Research and Development for the Hudson Pulp & Paper Co., So. Windham, Maine.

*Samuel J. Quattrocchi* is now Mill Manager of the Howard Smith Paper Mills, Ltd., Cornwall, Ont.

*Howard R. Rickards* is now General Manager of the Pennsylvania General Paper Corp., Coatesville, Pa.

*Samuel J. Robinson* is now President of Publishers Paper Co., Oregon City, Ore.

*Alfonso M. Saenz* of the Owens-Illinois Glass Co., has been transferred from Big Island, Va., to Jacksonville, Fla., as a Project Engineer.

*Leslie S. Simser,* formerly of American Cyanamid Co., is now a District Sales Representative of Penick & Ford Ltd., Inc., Cedar Rapids, Iowa.

*Albert J. Smith* is now Sales Manager of Ross Midwest Fulton Corp., Dayton, Ohio.

*John F. Steedley,* formerly of Bowaters Research & Development, Inc., is now Chief Engineer of Southern Land, Timber & Pulp Co., Atlanta, Ga.

*Edgar L. Stentz* is now Vice-President of the Eastern Mill Division, Packaging Corp. of America, Rittman, Ohio.

*Robert E. Stutz,* formerly of Western Pine Association is now in the Technical Sales Department of Chapman Chemical Co., Memphis, Tenn.

*Edward H. Tuton* is now Manufacturing Manager of the Vellumold Co., Worcester, Mass.

*H. Alan Weisel,* formerly of the University of Maine, is now a Project Leader for the P. H. Glatfelter Co., Spring Grove, Pa.

*William G. West,* formerly of the Borden Chemical Co., is now Sales Manager for the Stanley Chemical Co., E. Berlin, Conn.

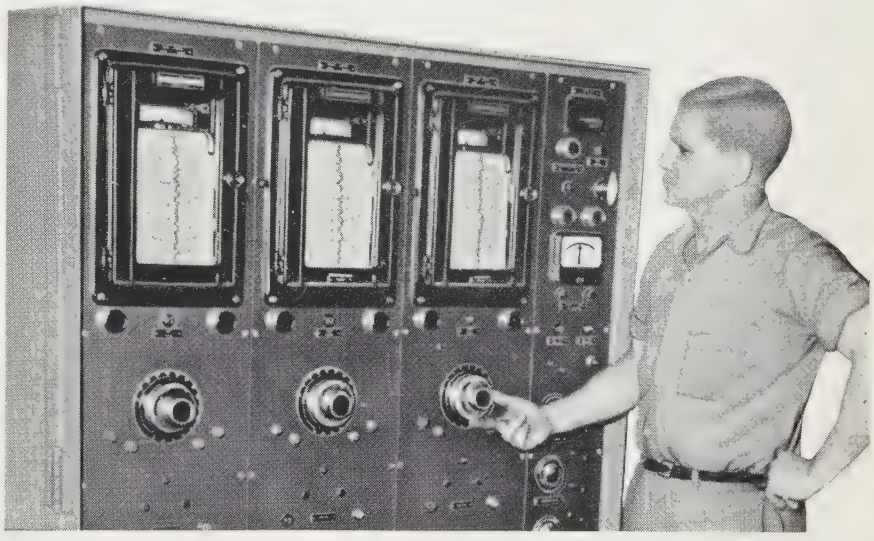
* * *

E. R. Morton has succeeded W. F. Furter as the official representative of du Pont of Canada, Ltd., Montreal, P. Q., in the Technical Association.

Thomas A. Jones has succeeded James Boyd (retired) as the official representative of Manchester Machine Co., Middletown, Ohio.

James H. Maddox has succeeded W. S. Miller as the official representative of Huffman-Wolfe Southern Corp., Atlanta, Ga., in TAPPI.


## Automatic HURLETRON Caliper and Weight Control... assures a New Standard of Quality for Paperboard-Makers



Under the watchful eyes of Hurletron Caliper and Weight Control, fluctuations at the wet end of the paperboard machine are automatically held to *plus or minus one point.* This control system continuously inspects the paper web to detect out-of-caliper conditions or variations in basis weight, and it instantly and *automatically* corrects for irregularities as soon as a trend has been established. Hurletron Control also provides a continuous, permanent record of finished caliper at the dry end after the calender stack. In mills across the nation, the Hurletron is producing new economies... new uniformity... new standards of quality in board production! Write for details *today.*

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CHEMICAL PRODUCTION COSTS,
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A complete appraisal of your chemical purchasing practices might reveal areas where you can make significant savings . . . and your Columbia-Southern Representative is fully equipped to help you do such a job.

He'll help you determine whether you're set up for the most economical chemical storage and handling, for one thing. And he'll survey the various forms and grades of chemicals you are buying now. Very often a small change can result in big savings.

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Get in touch with your Columbia-Southern Representative, and review these questions with him. You'll be glad you did.

Columbia-Southern Chemical Corporation, One Gateway Center, Pittsburgh 22, Pa. Offices in fourteen principal cities. In Canada: Standard Chemical Limited.

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Barium Chemicals • Sulfur Chemicals • Agricultural Chemicals
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Muriatic Acid • Calcium Hypochlorite • Titanium Tetrachloride

# INDUSTRY NOTES

## *North American*

### Statistics

*Paper and Paperboard: First Quarter of 1960*

Production of paper and paperboard in the first quarter of 1960 established a new high at an estimated 8,800,000 tons. This figure was 8% above the first quarter 1959 total, and was only 2% less than the total amount of paper produced in the entire year 1925. Output, thus, quadrupled in three and a half decades.

The first-quarter 1960 high reflected strength in each of the major groupings. Paper production, at 4,000,000 tons, was 10% above the total for the first quarter of 1959 paperboard production, at 4.1 million tons, registered at 6% gain in the same comparable period, while output of construction paper and board, at about 780 thousand tons, showed a 3% rise. These gains are more impressive when it is realized that the totals for the first quarter of 1959 were themselves *new* highs for that period of the year, and in turn reflected sizable gains over 1958 levels.

The first-quarter gains were matched by equally strong gains throughout the industry. Thus, woodpulp production (data are available only for the first two months) was at an annual rate of 25 million tons, up 9% the same period of 1959, while woodpulp new supply (production plus imports less exports) was up 4%. Output of market pulp, incidentally, showed a particularly strong gain, but total new supply of market pulp was a shade below the 1959 level as a result of a reduction in market pulp imports and a major increase in the level of woodpulp exports. Wastepaper consumption showed a moderate gain during the early months of 1960 over the 1959 period.

These gains in output of paper and paperboard were achieved with relatively moderate increases in employment. Total employment at pulp, paper, and paperboard mills climbed only 1% from the year-earlier level during the month of January, 1960 (the latest available figure), while the number of production workers remained unchanged.

Dollar sales in the paper and allied products industry stayed close to the $12 billion per year level in the early months of 1960, but no data are yet available to indicate the rate of earnings on the sales. Preliminary government data on the financial performance of the industry in 1959 just became available within the last week or so. These data show that sales of all corporations in the industry in 1959 totaled $11,842 million to establish a new all-time high. Production of paper and paperboard, incidentally, totaled 34,051,000 tons which, as has been noted many times before, was also a new high. Earnings on the record sales amounted, after taxes, to $619 million, or 5.2% of the total sales volume. This rate of return may be compared to the 4.7% shown in both 1957 and 1958 and the 5.6% average of the 1952–56 period. The 1959 rate of profits relative to net worth was 9.3%, compared to 8% in 1958, 7.8% in 1957 and a 9.4% average for the five-year period 1952–56.

Although some small percentage of the total output of the paper and paperboard industry during the first quarter of 1960 remained as inventories in the channels of distribution, these inventories are still probably somewhat low with respect to the present volume of requirements. Demand for paper and paperboard for inventory purposes may be expected to diminish during the remainder of 1960, but this will be largely offset by gains in consumption requirements.

For the economy as a whole, and for the paper industry in particular, no major imbalances were in evidence. Total consumption of goods and services may be forecast eo expand in line with its long term trend, thus rising 3 to 4% above its average 1959 level in 1960. Consumption of paper and paperboard may show a similar gain, indicating a domestic production total for 1960 as a whole close to the annual rate achieved in the first quarter of the year.

## *Overseas*

### Sweden

*Clupak Production Started by Dynas Aktiebolag*

Clupak extensible paper has now entered the European market with the start of full-scale production by Dynas Aktiebolag, in Sweden, of the tough, tear-resistant and shock-absorbing paper.

Under license from Clupak, Inc., Dynas is producing the extensible kraft paper on its high-speed J. H. Voith fourdrinier machine at its mill in Vaja, Sweden, and shipments of the paper already have begun to the United Kingdom and other European countries.

The Dynas 205-in. papermaking machine, to which an extensible unit has been added, has a capacity of 42,000 tons of paper a year and is capable of running a full range of unbleached kraft paper.

## *Pulp and Paper Manufacturers and Converters*

### Allied Paper Corp.

*Allied Paper Acquires Egry Register Co.*

Egry Register Co. of Dayton, Ohio, has been acquired by the Allied Paper. Egry, founded in 1897, is one of the oldest companies engaged in the manufacture of continuous printed business form systems.

Arnold H. Maremont, chairman of the board, announced that two smaller companies engaged in the manufacture of business forms, have also been acquired. These are: the Stephen Greene Co. of Philadelphia, Pa., and the American Register Co. of Boston, Mass. The three units have a total sales volume in excess of $10, million per year.

### Appleton Coated Paper Co.

*Scholarships Established*

The Charles Samuel Boyd Memorial Scholarship, an annual 4-year scholarship to an accredited college or university, has been established by The Appleton Coated Paper Co. Each award will be $500 for the academic year and will be renewable annually for a maximum of 3 additional years if satisfactory progress is maintained.

The scholarship is named after Charles S. Boyd, who founded The Appleton Coated Paper Co. in 1907 and who was its President for 41 years and Board Chairman for 4 years, before his death in 1952. He graduated from Lawrence College in 1893, was a trustee of the college for many years, and did much to encourage college attendance.

### Brown Co.

*Appointment*

Leonard A. Pierce, Jr., has been named president of Brown Co., northern New England pulp, paper, and forest products manufacturers. Mr. Pierce, a native of Houlton,

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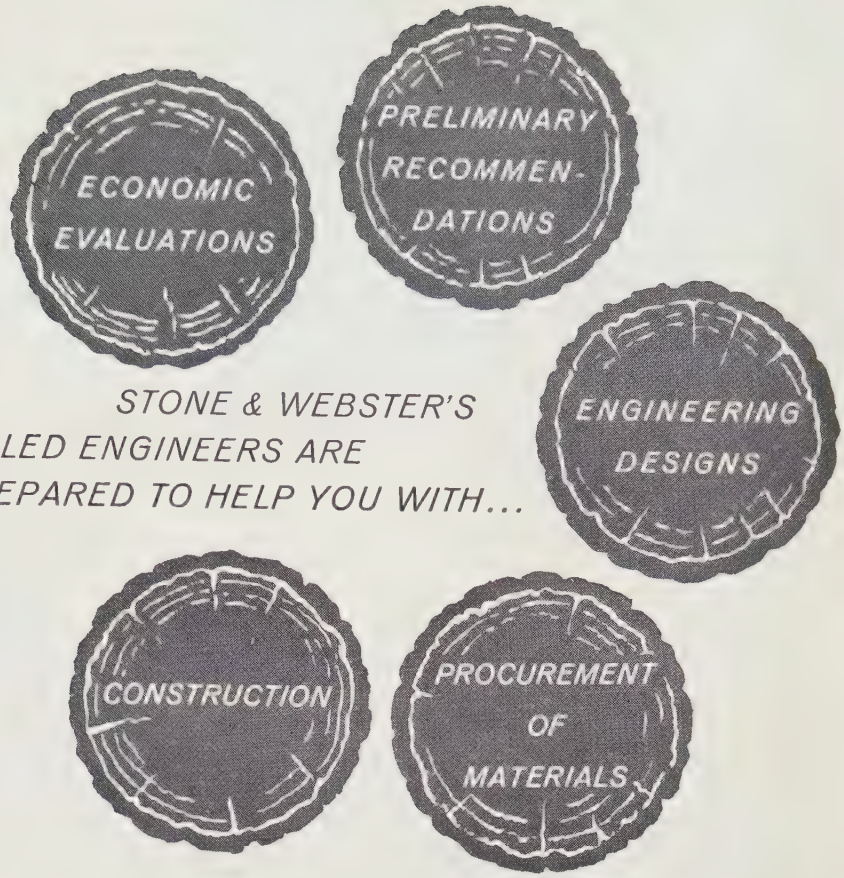


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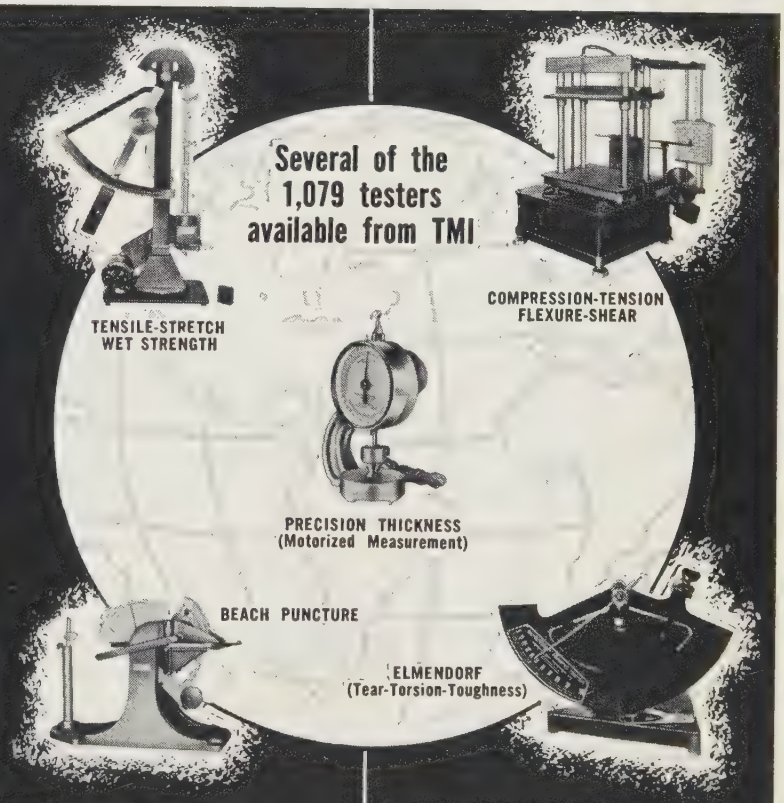


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# TESTING MACHINES INC.

72 Jericho Turnpike • Mineola, L. I., New York

The finest Test Equipment for ALL Industries

*Leonard A. Pierce, Jr., Brown Co.*

*Arthur W. Plummer, Hudson Pulp & Paper Corp.*

Me., now vice-president-operations of Penobscot Chemical Fibre Co., Old Town, Me., assumed the Brown Co. post after April 18.

**Clupak, Inc.**

*Advances in Extensible Isotropic Paper*

A new form of Clupak extensible paper which has all-directional stretch has been produced on 60-in. wide pilot machinery. Research and equipment design on the all-directional (isotropic) extensible paper are the major items in Clupak's current research program. The latest research developments were reported at the second annual Clupak Research and Operations Symposium held in Jacksonville, Fla., on April 20, 1960. Attending the symposium, which was under the chairmansip of Hewitt Welsh, vice-president and technical director of Clupak, Inc., were 40 representatives of the 11 U. S. and Canadian Clupak licensees, Beloit Iron Works (which manufactures the extensible machine units), Raybestos-Manhattan, Ltd. (rubber blanket manufacturer), and Clupak, Inc.

**Federal Paper Board Co., Inc.**

*$12 Million Expansion*

Federal Paper Board is embarking upon a $12 million expansion program. The expansion is centered around the Richmond, Va., Seaboard Mill of Federal's Manchester Board and Paper Co. Division. The program involves the installation of a cold soda process to produce pulp from hard woods, an additional machine for the production of paperboard from bleached virgin pulp, and the construction of a carton converting plant. The new carton plant and the pulping process are expected to be in operation by early 1961, and the new paperboard machine installed and operating before the end of 1961; it will have an annual capacity of about 60,000 tons.

**Fibreboard Paper Products Corp.**

*Appointments*

Two appointments in the Paperboard Division of the corporation have been announced. Ralph G. Beauregard was named manufacturing manager for Fibreboard's entire Paperboard Division, and Ralph P. McDonald was appointed to succeed Mr. Beauregard as manager of the Stockton board mill.

**Hamilton Paper Co.**

*Appointments*

The Hamilton Paper Co. announces the appointment of John Kauffmann to the position of assistant manager of the Michigan Division, effective May 1, 1960.

Mr. Kauffman is also chief engineer of the Michigan Division and assistant secretary of the company.

**Hammermill Paper Co.**

*Merger with U. S. Envelope*

The Boards of Directors of Hammermill Paper Co. and United States Envelope Co. have entered into an agreement providing for the merger of the two companies. The agreement is subject to the approval of the stockholders of both companies.

**Hudson Pulp & Paper Corp.**

*Appointment.*

Hudson Pulp and Paper Corp. has announced the promotion of Arthur W. Plummer, formerly associate director of research and development, to the position of assistant vice-president and director of research and development.

Mr. Plummer had extensive professional and administrative experience in process development and chemical engineering research with the Kimberly-Clark Corp. before joining Hudson. He is chairman of the TAPPI Chemical Engineering Committee and a member of the APPA Committee on Coordination of Research. He has had published a number of papers in the chemical engineering field.

*Joseph D. Chadderdon*

**KVP Sutherland Paper Co.**

*Appointment*

Joseph D. Chadderdon has been named supervisor of plant technical service at the KVP Division of KVP Sutherland Paper Co., Kalamazoo, Mich.

**The Mead Corp.**

*Mead Merit Scholarships*

This year's winners of the two National Merit Scholarships sponsored by The Mead Corp. are Paul Frank Winkler, Jr., of Chillicothe, Ohio, and David Owen Findley of Rome, Ga. Their awards are the seventh and eighth given by Mead since the program was inaugurated five years ago.

Both scholarship winners are rated as outstanding students by their respective principals, have maintained straight "A" averages throughout their high school careers, rank at the top of their respective senior class, and have demonstrated leadership in extra curricular activities.

**Oxford Paper Co.**

*Appointments*

Harold M. Annis, vice-president, research, announced that Jasper Mardon is joining the research department of Oxford Paper Co. as chief papermaking research engineer. He will be located at Oxford's Research Laboratories at Rumford, Me., commencing his work there in June.

Mr. Mardon comes to Oxford from Anglo Paper Products of Quebec, P.Q., where since 1954 he has been Head of the Papermaking Research Group. He, together with associates, received the Weldon Gold Medal from the Technical Section of the CPPA in 1956 and the Insignia Award from the City and Guilds of London Institute in 1959. He is an Associate of the Royal Institute of Chemistry, a graduate member of the Institution of Chemical Engineers, a member of TAPPI, the Technical Sections CPPA and BPBMA, and APPITA.

**Packaging Corporation of America**

*Appointments to Paperboard Operations*

Three new vice-presidents were named to head the

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That's all it takes to measure samples up to 0.25" thick with the motorized Gurley Stiffness Tester. It easily handles tissue, newsprint, book, bonds, ledgers, industrial papers, cardboard, carton stocks; and permits a wide range of readings from 1 to 3,358,720.

Precision strip cutter also available. Write for Bulletin 1400, describing complete line of Gurley paper testers.

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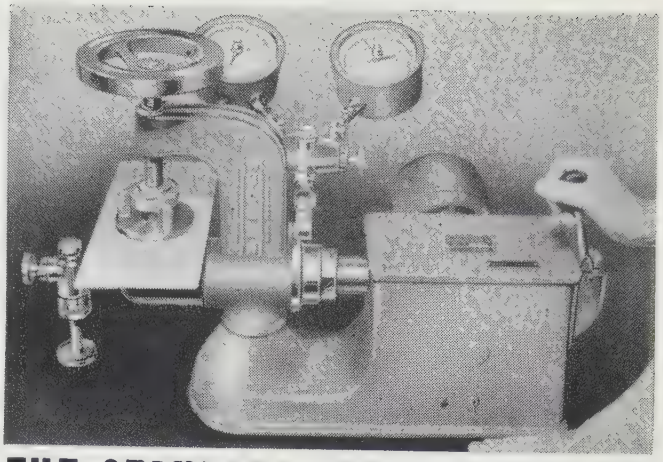

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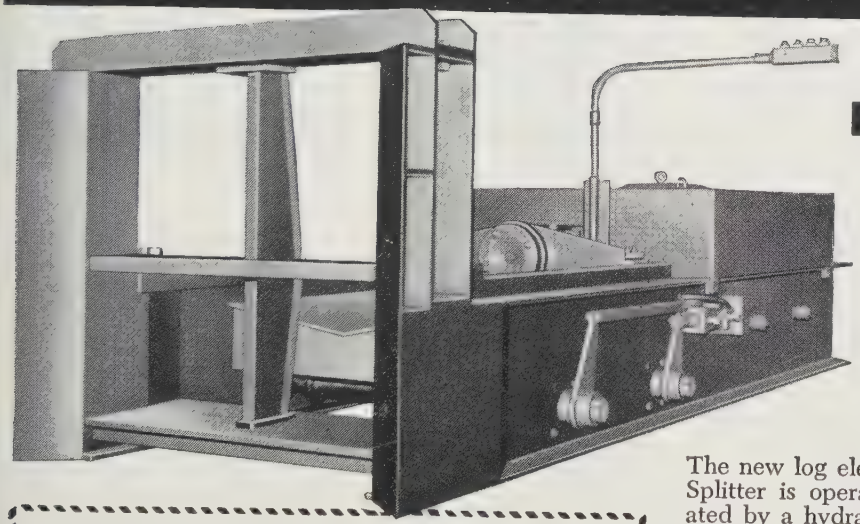
## NEW! Log Elevator Mechanism



### Makes the Carthage Hydraulic Log Splitter
### EVEN EASIER to INSTALL
### EVEN EASIER to SERVICE

The new log elevator of the Carthage Hydraulic Log Splitter is operated through a series of levers actuated by a hydraulic cylinder mounted on the outside of the splitter frame. No pit is required, so that the Splitter is easy to install and easy to move from location to location. Can be placed on cross timbers – no bolting-down needed. Cylinder rings and packing are quickly accessible for low-cost maintenance. ONE STROKE splits logs into four pieces (6-way axe also available). Fast, safe, trouble-free push-button operation. 30" and 38" log diam. splitters available. Service-proved since 1950.

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# 69 GE BRIGHTNESS

"Adding PQ Silicate to the bleach liquor" says the Manager . . . "creates a buffering action so that oxygen release in the bleaching cycle is controlled." Deeper penetration of the fiber results with corresponding uniform brightness. Silicate maintains a relatively stable pH over a wide range of concentration.

The PQ silicate generally chosen for bleaching is "N" ($\%Na_2O:\%SiO_2$ 1:3.22, 41° Baume) which is available from any of our nine plants in bulk, carload or truckload. Less than truckloads from distributor stocks in over 65 cities.

PQ silicates are important components in the bleaching of many kinds of pulp . . . soda, sulphate, and mixed pulp. Our bulletin *"PQ Soluble Silicates in the Pulp and Paper Industry,"* tells you more about bleaching with sodium silicates as well as describing other paper mill applications.

**PHILADELPHIA QUARTZ CO.**
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***Left to right: Henry B. Weis, Gordon B. Bonfield, Sr., and B. L. Stentz***

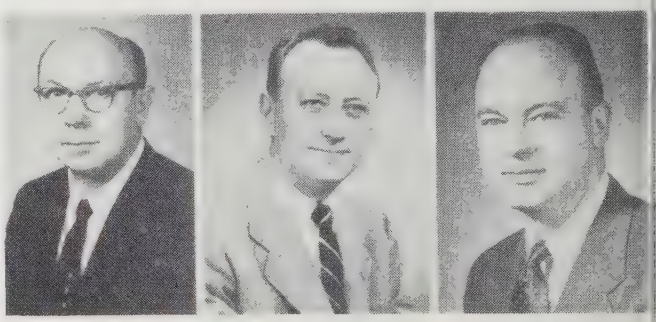
eastern, central, and western paperboard operations of Packaging Corporation of America.

Henry B. Weis, of Quincy, Ill., named vice-president, paperboard division-western region; Gordon B. Bonfield, Sr., of Grand Rapids, Mich., named vice-president, paperboard division-central region; E. L. Stentz, of Wadsworth, Ohio, named vice-president, paperboard division-eastern region.

*Appointments to Container Plant Operations*

Three vice-presidents have been appointed to head the corporation's eastern, central, and western container plant operations. The company's container division operates 22 plants in 13 states extending from New York to Utah.

Herman L. Brunner, of Quincy, Ill., named vice-president, container division-western region. E. W. Lewis, of Wausaw, Wis., named vice-president, container division-central region. S. F. Allison, of Akron, Ohio, was named vice-president container division-eastern region.



***Left to right: Herman L. Brunner, E. W. Lewis, and S. F. Allison***

**Paramount Paper Products Co.**

*Expansion*

A major step in its 1960 plant expansion plan has been taken by Paramount Paper Products Co. of Omaha, Neb., with announcement of the establishment of a branch plant and warehouse in the Boston, Mass., area. The company is one of the nation's largest manufacturers of labels and specialty tapes.

William McLaughlin, formerly Paramount regional manager in New England, will supervise all operations of the new plant.

**Riegel Paper Corp.**

*Expansion in Atlanta*

Riegel announced the letting of contracts for a new 150,000-sq. ft. plant for its Quality Lithographing Division. The new plant, designed by Eastern Engineering Corp., Atlantic Co., will be located on a 16-acre site on Old Peachtree Road and cost approximately $2,000,000. It is expected to be completed late in 1960.

*Paper Scholarship Awarded*

Paul Irving West of Finesville, N. J., was declared the winner of the 1960 Riegel Paper Corp. Scholarship at the Phillipsburg High School, Phillipsburg (N. J.).

The Riegel scholarship covers a period of four academic years at any accredited college or university of the winner's choice, and provides up to $1000 each year for direct college expenses.

**St. Regis Paper Co.**

*Over One Million Trees Planted*

The largest single tree planting project in the state of Wisconsin is being undertaken this spring by the Rhinelander Paper Co., a division of St. Regis. As a result of its successful forest management program, 1,150,000 trees are now being planted on the company's lands from Rhinelander to Ashland.

*Appointments*

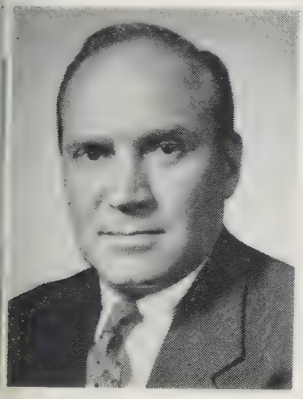
Benton R. Cancell, executive vice-president in charge of operations of St. Regis Paper Co., has been elected a director. He had been president of Rhinelander Paper Co., which became a division of St. Regis on Jan. 1, 1956.

T. Marcus McClellan, Jr., president of Nifty Manufacturing Co. (formerly Birmingham Paper Co.), now a division of St. Regis Paper Co., has been elected a director of St. Regis.

W. Irving Osborne, Jr., chairman of the board of Cornell Paperboard Products Co., Division of St. Regis Paper Co., has been elected a director of St. Regis.

Directors of the company elected Philip B. Duffy and John A. McDermott vice-presidents of the company.

Mr. Duffy, who is executive vice-president of St. Regis

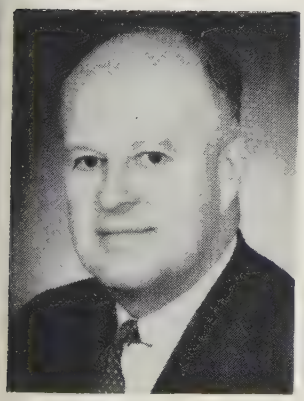


***Benton R. Cancell***

***T. Marcus McClellan, Jr.***

Container Division, was named vice-president-corrugated containers; and Mr. McDermott, general manager of all pulp and paper manufacturing, has been named vice-president in charge of pulp and paper manufacturing.

The following personnel changes have been made in the



***W. Irving Osborne, Jr.***

***John A. McDermott***


How Whippany Paper Company, Inc.

**KEEPS COSTLY FELTS TROUBLEFREE**

**from "TOP" to "BOTTOM"...**

Typical application of MOUNT HOPE ROLLS on top finishing felt.

with

**Mount Hope ROLLS**

In the production of kraft paper for 9 pt. test liner, Whippany Paper Company, Inc., Whippany, N. J., runs board 234 inches wide at 500 to 750 F.P.M. on one of its cylinder machines. MOUNT HOPE ROLLS mounted on the machine not only assure top efficiency and service life from the costly, extra-wide felts used, but simultaneously protect the high quality of the board.

On the top finishing felt MOUNT HOPE ROLLS preserve elasticity and nap, minimize dangers of "picking" or "checking". On the bottom wet felt, they keep the weave open, restore the felt to full width on each revolution, keep the seam straight. On both felts, they assure even water drainage. Result: consistently smooth, economical production.

A MOUNT HOPE Engineer will be glad to show you how MOUNT HOPE ROLLS will protect quality, productivity, and operating economy in *your* mill. Simply fill out and mail coupon.

**MAIL THIS COUPON NOW! . . .**

Mount Hope

**MOUNT HOPE MACHINERY COMPANY**
62 Fifth Street Taunton, Mass.

Please have a MOUNT HOPE Engineer show me where MOUNT HOPE ROLLS can improve the economy and efficiency of my operations.

Plants at Taunton, Mass. and Charlotte, N. C.

NAME _____

TITLE _____

COMPANY _____

STREET _____

CITY _____ ZONE _____ STATE _____

Central Engineering Division: Henry W. Wegner has been transferred from St. Paul and Tacoma Lumber Co. to the Central Engineering Division and taken on new duties as executive sawmill engineer. He will make his headquarters in the Washington Building in Tacoma, Washington.

Robert B. Young, Jr., has joined the Central Engineering Division as a staff power engineer. He will be stationed at the Division headquarters in Jacksonville, Fla.

James L. Gillespie and H. Scott Oglesby have joined the Central Engineering Division staff as project engineers. They will make their headquarters at the Jacksonville office.

Harry K. Collinge has been elected a vice-president of North Western Pulp and Power, Ltd., jointly owned by St. Regis Paper Co. and North Canadian Oils, Ltd. Mr. Collinge is resident manager of the North Western Pulp & Power mill at Hinton, Alberta.

Robert J. LaFond has been transferred to the technical service-to-manufacturing section of the technical services and control department as supervisor, pulp and paper group—printing papers.

Mr. LaFond has been with St. Regis since 1956 as group leader of graphic arts research. Before that time, he was with Marathon Corp. as a senior process engineer in the printing development group.

**Scott Paper Co.**

*Foundation Scholarship Award*

A top-level University of Wisconsin engineering student from Wausau has received the Scott Foundation Scholarship award for each of his junior and senior years.

Receiving the award is Donald E. Dau, son of Mr. and Mrs. Edwin Dau, 933 S. Ninth Ave., Wausau, Wis.

The award, one of the educational programs of Scott Paper Co., Chester, Pa., was established at the UW in 1957 as a means of helping top-ranking engineering students to complete their education.

Each year that a scholarship winner is enrolled, the Scott Foundation also makes a second unrestricted grant of $1000 to Wisconsin's College of Engineering.

**Standard Packaging Corp.**

*Appointment*

Harry G. Davis has joined Standard Packaging as division manager of the Chemical Fine Paper & Board Division, and will make his headquarters in Holyoke, Mass.

**Watervliet Paper Co.**

*Appointment*

Mr. Valentine Friedrich, Jr., has been appointed as division manager of the Watervliet, Mich., division of the Hammermill Paper Co.

Friedrich was vice-president in charge of manufacturing at Beckett Paper Co., Hamilton, Ohio, where he served for 37 years. He is a graduate of MIT in chemical engineering, and is a member of TAPPI and PIMA.

*Valentine Friedrich, Jr.*

## *Educational Institutions*

**Engineering Schools Enrollment***

The American Society for Engineering Education and the Federal office of Education report that enrollment in engineering schools has declined for the second straight year. Total students enrolled for first engineering degrees in the last years are:

| | |
|---|---|
| 1957 | 257,77 |
| 1958 | 249,95 |
| 1959 | 240,06 |

However, because of the high enrollments in the mid-1950 the numbers of degrees granted and those enrolled for advanc degrees continue to rise. The figures given are as follows:

Number enrolled in work for the master's degree—

| | |
|---|---|
| 1958 | 27,43 |
| 1959 | 29,09 |

Number of master's degrees—

| | |
|---|---|
| 1957–58 | 575 |
| 1958–59 | 672 |

Number enrolled in work for doctor's degree—

| | |
|---|---|
| 1958 | 476 |
| 1959 | 564 |

Number of doctor's degrees—

| | |
|---|---|
| 1957–58 | 64 |
| 1958–59 | 71 |

**The Institute of Paper Chemistry**

George D. Jernegan has been appointed dean of student He will be concerned with student welfare, and will have re sponsibility for student housing, summer and permanent em ployment, guidance and counseling, and related activities.

*George D. Jernegan*

Mr. Jernegan received a B.A. degree from Beloit College in 1943, the M.A. degree from the State University of Iowa in 1947, and did further graduate study at the University of Southern California. His graduate work was in the field of guidance, counseling, and student personnel activities. He has had experience in high school teaching, and has served as an assistant professor of psychology at Beloit College (1947–53) and Long Beach State College (1950–51). He has been on the staff of The Institute of Paper Chemistry since 1954, and was appointed director of continuing educa tion in 1958, a position he will continue to fill. He is th author of "A Guide to Career Opportunities in the Pul and Paper Industry."

**University of Maine**

About 235 representatives of leading pulp and paper an allied concerns from many parts of the nation attended th annual Open House and Research Days program at th University of Maine on Friday, April 29.

The program, sponsored by the University and the U. o M. Pulp and Paper Foundation, included 13 laboratory dem onstrations of current research projects in the area of pul and paper technology, a luncheon meeting with speaker from industry, two afternoon panel discussions featuring stu dents and industrial representatives, and a dinner meeting a the Penobscot Valley Country Club.

Activities listed for Saturday included a continuation of th laboratory demonstrations, inspection of laboratories, an informal consultations with staff members and students.

Fred Soderberg, vice-president of F. C. Huyck and Sons Rensselaer, N. Y., presided at the luncheon meeting. Speak ers were Curtis M. Hutchins, chairman of the board of th

* Earl Ubell in the New York *Herald Tribune*, Sunday, April 24.

Dead River Co., Bangor; Walter C. Shorter, vice-president of Union Bag-Camp Paper Corp., New York City; W. Wyatt Shorter, of the Union Bag-Camp Paper Corp., Franklin, Va.; and Winship B. Moody, technical sales representative, Hercules Powder Co., Holyoke, Mass.

The speaker for the dinner meeting was Dr. Lincoln R. Thiesmeyer, president of the Pulp and Paper Research Institute of Canada. J. L. Ober, Beverly, Mass., retired vice-president of the Scott Paper Co. and president of the U. of M. Pulp and Paper Foundation, presided at the evening session.

**Western Michigan University**

Six students, from among 42 tested, have been named recipients of $500 annual scholarships in paper technology at Western Michigan University, Kalamazoo, to begin in the fall semester of 1960, according to Dr. A. H. Nadelman, head of the paper technology department.

Finishing first in the competition was John Stephen Taylor, Benton Harbor, Mich., who will receive a Penick & Ford, Ltd., scholarship in paper sales.

The next three finishers all receive Dow Chemical Co., scholarships in paper technology: Lee Cowle Swenson, Whitehall, Mich.; David L. Rumberger, Portage, Mich.; and Ray Lee Hudson, Doylestown, Ohio.

Receiving paper sales scholarships from the Salesman's Association of the Paper Industry are Larry D. McArthur, Columbiaville, Mich., and Edwin J. Grossenbacher, Doylestown, Ohio.

All awards are for $500 annually and are renewable throughout the 4-year college career of the students.

*Earnest E. Ludwig*

Earnest E. Ludwig, retired vice-president and manager of the Kalamazoo office of Berminham & Prosser Co., has been named executive secretary of the Paper Technology Foundation, Inc., at Western Michigan University.

The Foundation was created in 1958 and Mr. Ludwig will be the first person to devote full attention to its operation and development.

In addition to his business affairs, Mr. Ludwig served as a city commissioner in Kalamazoo for several years, has been president of the Kalamazoo Community Chest, and is on the national board of missions of the Evangelical and Reformed church.

## *Industry Suppliers*

**Allied Chemical**

*Appointments*

Frank J. Woods has been appointed director of sales for Allied Chemical's General Chemical Division.

With the division 22 years, Mr. Woods has been heavy chemical sales manager for the past ten. Prior to that he was insecticide sales manager for seven years.

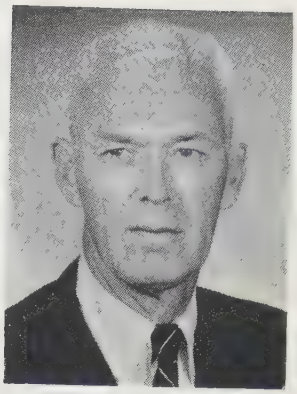
**Allis-Chalmers Mfg. Co.**

The appointment of Frank R. Forrest as consulting engineer, pulp and paper industry, has been announced by Allis-Chalmers Industrial Systems Dept.

Mr. Forrest is widely known in the pulp and paper industry through his nearly 40 years with Allis-Chalmers, many of them as an application engineer in the centrifugal pump department.

He holds various patents on equipment for storing and handling paper stock, and is a member of the Fluid Mechanics

*F. R. Forrest, Allis-Chalmers Industrial Systems Dept.*



*Sam Crocker, Jr., Bauer Bros.*

Committee, Engineering Division, Technical Association of the Pulp and Paper Industry.

Election of J. D. Greensward as president, Canadian Allis-Chalmers, Ltd., a wholly owned Allis-Chalmers subsidiary, was announced April 8, 1960. He succeeds Harold M. Schudt who has been named director of manufacturing, Allis-Chalmers International.

**The V. D. Anderson Co.**

*New Bulletin on Fiber Presses*

A new bulletin released by V. D. Anderson deals with the FiberPress method of removing liquor and dissolved solids from semichemically cooked chips. Described are the two-stage FiberPress, its mechanical advantages, maintenance requirements as well as engineering and research services. Detailed drawings and photographs of the FiberPress together with comparative photographs of cooked chips before and after processing are also shown.

For your copy of Bulletin FP360 write to The V. D. Anderson Co., 1935 W. 96 St., Cleveland 2, Ohio.

**The Atlantic Refining Co.**

*Appointment*

Atlantic Refining has announced the appointment of Frank W. Chapman as manager of product development and technical services division of the firm's marketing department He succeeds John C. Geniesse who is retiring after 35 years' service with the company.

**Bauer Bros. Co.**

The Bauer Bros. Co., Springfield, Ohio, announces a change of address for Mr. Sam Crocker, Jr., of the company's southern sales division. His new address is 15 Lakeside, Pensacola, Fla.

**The Emerson Mfg. Co., John W. Bolton & Sons, Inc., Div.**

*New Reciprocating Shower*

Emerson has introduced a new reciprocating shower pipe for use in paper mills using either fresh or white water systems. The new shower makes an important contribution to an increase in wire life, an improvement in sheet formation, a decrease in downtime, and conservation in the use of water.

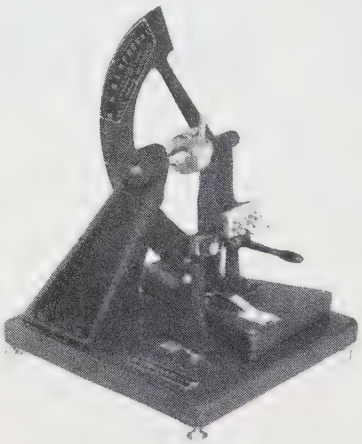
Available in diameters ranging from $1^1/_2$ to 6 in., and in lengths up to 375 in., Emerson's reciprocating shower comes as a complete unit. The reciprocating movement is actuated by an automatic, reversing pneumatic cylinder which is adjustable to the desired length of stroke and speed. The pipe is supported by rubber rollers which are mounted on sealed bearings.

Equipped with anticorrosive nozzles in any orifice required, the reciprocating shower has the standard Emerson features of fan spray and built-in cleanout mechanism. Stainless steel brushes are internally positioned in line with

## ELMENDORF TEARING TESTER

The Elmendorf Tearing Tester for many years has been recognized as the standard of the World for tearing tests on paper. The underlying principles of the Elmendorf Tearing Tester have been proved correct many times over. It is not surprising, then, that the instrument has found acceptance in other fields of testing.

Now the Elmendorf Tearing Tester can be fitted with attachments to make Impact, Toughness and Torsion Tests on paper, plastic films, textiles, etc. and still be used as a tearing tester.



Elmendorf Tearing Tester with Toughness Attachment

**ELMENDORF TOUGHNESS ATTACHMENT** Ideal for testing materials subjected to rapidly applied or varying tensile loads.

**ELMENDORF TORSION ATTACHMENT** Permits testing of highly directional materials where failure normally follows the line of least resistance.

**SPENCER IMPACT ATTACHMENT** For testing impact strength of plastic films, paper and laminates.

*Write for complete details.*

**THWING-ALBERT INSTRUMENT COMPANY**
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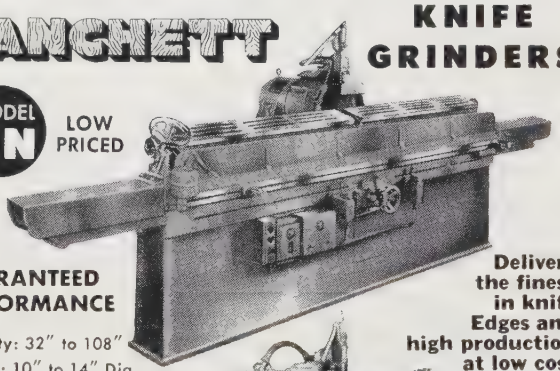
**HANCHETT KNIFE GRINDERS**

MODEL DN LOW PRICED



**GUARANTEED PERFORMANCE**

Capacity: 32" to 108"
Wheels: 10" to 14" Dia.
Table Drive — Timing Belt with Elec. Reversing Motor
Motor — 3 H.P.

**Delivers the finest in knife Edges and high production at low cost**

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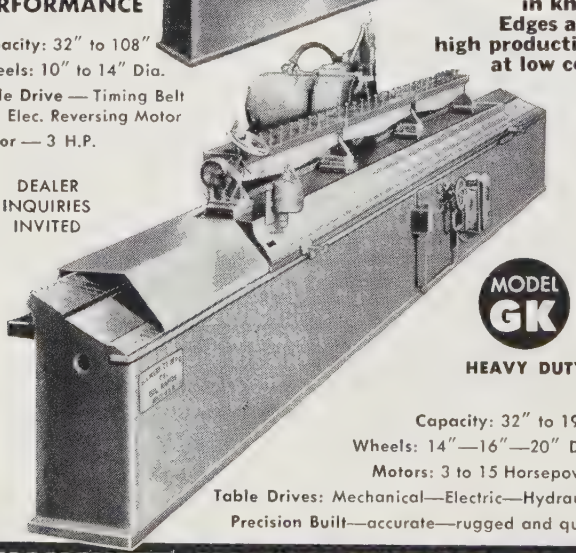
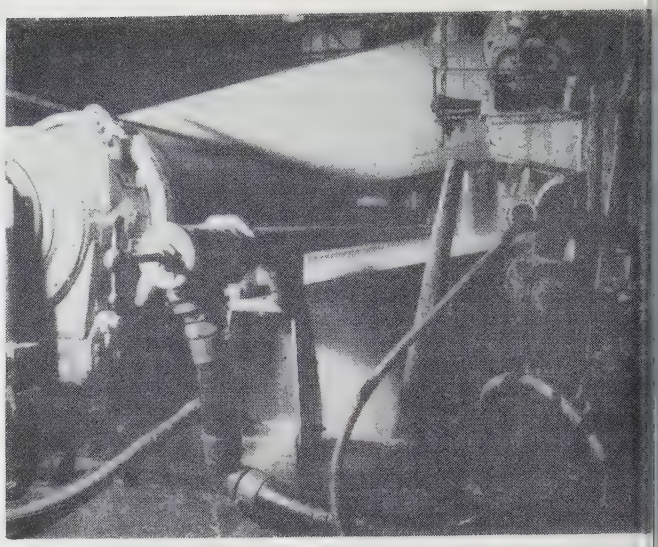


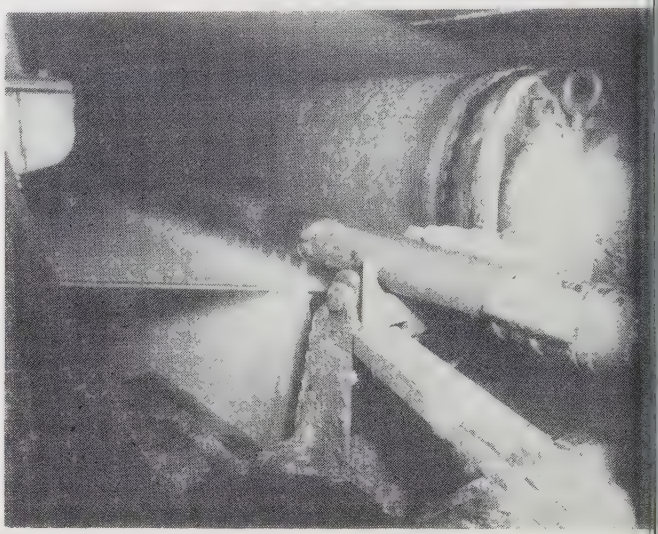
MODEL GK HEAVY DUTY

Capacity: 32" to 196"
Wheels: 14"—16"—20" Dia.
Motors: 3 to 15 Horsepower
Table Drives: Mechanical—Electric—Hydraulic
Precision Built—accurate—rugged and quiet

**HANCHETT MANUFACTURING CO.**
Main Office: BIG RAPIDS, MICHIGAN
West Coast: PORTLAND 1, OREGON

*The reciprocating shower viewed from the front of the machine, showing a supporting rubber roller and the handle to the built-in cleanout mechanism*



*The reciprocating shower shown from the back of the machine with partial view of the automatic reversing pneumatic cylinder which actuates the reciprocating movement*

the nozzles. By turning a handle at the front side of the machine, brushes clean the nozzle openings, while simultaneously a flush valve opens at the back side of the machine and flushes the entire pipe of any foreign material.

*Baldwin Named Market Research Head*

Benjamin C. Baldwin of Groton, Mass., has been appointed director of market research of John W. Bolton & Sons, Inc. and The Emerson Manufacturing Co. Division.

Previously, Mr. Baldwin was associated, for five years, with the Simonds Saw and Steel Co., Fitchburg, Mass., in a similar capacity.

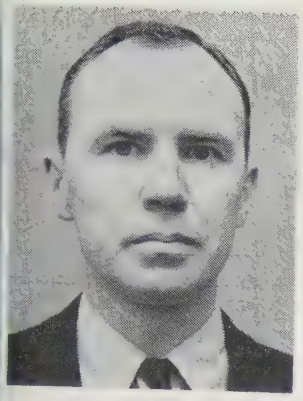
**The Borden Chemical Co.**

*Appointments*

John C. Becker, Jr., has been appointed to the position of assistant technical service manager for the Polyco-Monomer Dept.

He will concentrate primarily on the development of new polymer emulsions and related products for the paint industry and will make his office in Leominster, Mass.

Nick Mechales has been appointed a technical sales representative for the Polyco-Monomer Dept.



*Benjamin C. Baldwin, John W. Bolton & Sons, Inc.*

*Robert B. Mesrobian, Continental Can Co.*

Mr. Mechales will be responsible for the sale of Polyco-Monomer's full line of synthetic resins, to the adhesive, paint, paper, and textile industries. His sales area will include the states of Illinois, Indiana, Michigan, and Kentucky, and his headquarters in Elmhurst, Ill.

M. C. Wakefield, Jr., has been appointed to the position of sales manager of the Polyco-Monomer Dept. of The Borden Chemical Co., a Division of The Borden Co.

Mr. Wakefield joined Borden Chemical in 1957 as Midwest district sales manager. In his new position, he will direct the sales organization of Polyco-Monomer in all product and industry areas.

**California & Hawaiian Sugar Refining Corp.**

*George W. Aljian to Retire*

George W. Aljian, vice-president of C and H Sugar Refining Corp., retired April 30 after 41 years of service. He was director of purchasing and packaging between 1945 and 1958 and had been purchasing agent from 1933 to 1945.

In 1951, Mr. Aljian was also named Coordinator of the By-Products Project of the Hawaiian Sugar Planters' Association of Honolulu. Mr. Aljian is past president of the National Association of Purchasing Agents and of the Purchasing Agents' Association of Northern California. He was Editor-in-Chief of the "Purchasing Handbook," a 1500-page volume published by McGraw-Hill in 1958, and served for 5 years as Chairman of the National Committee on Education.

**Cavedon Chemical Co.**

*FDA Approves Cavcocide*

Approval of Cavcocide, a product used in the manufacture of paper and pulp, has been received from the Food and Drug Administration according to Norman Alper, vice-president of Cavedon Chemical Co., Woonsocket, manufacturers of the product.

Cavcocide is a fortified chlorine dioxide solution used in paper mills to prevent the formation of slime.

**Continental Can Co.**

*General Packaging Research and Development Division*

A General Packaging Research and Development Division has been established by Continental Can to coordinate the research programs presently undertaken separately by six of its divisions. The new Division will do research on the improvement of containers derived from paper, plastics, and combinations of the two, and on closures for glass and other containers.

Dr. Robert B. Mesrobian, who had been general manager of Continental's paper and plastic container research and development, and formerly the company's associate director of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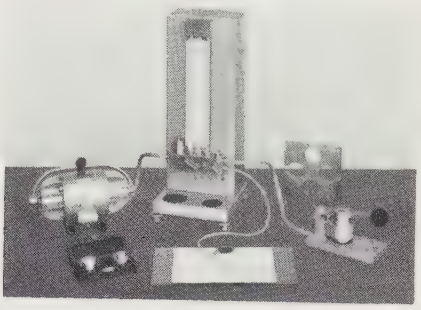
**BENDTSEN TESTER**

ONE LIGHTWEIGHT MACHINE THAT TESTS
**PAPER & PAPERBOARD**
for
SMOOTHNESS . . . POROSITY . . . HARDNESS
*Instantaneously*



INSTANTANEOUS: No waiting — No scale adjustments.
ACCURATE: No oil or dust can enter instrument. Smoothness not effected by porosity.
VERSATILE: Completely self contained, portable, no special training required. Tests smoothness, porosity & printing hardness of paper & paperboards . . .

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This is the end result of the various processes and equipment which we have installed in pulp mills throughout North America. Send us details of your requirements.

**Chemipulp Process Inc.**
**Watertown, N. Y.**

*Associated with*
**Chemipulp Process Ltd., 253 Ontario St., Kingston, Ont.**

**Pacific Coast Representative**
**A. H. Lundberg, Inc., P. O. Box 186, Mercer Island, Wash.**

high polymer chemistry, will direct the new Division's activities.

General Packaging R&D is presently having a new center constructed for it in Chicago, for 1961 opening. The center will offer 145,000 sq. ft. of working space in a building adjacent to the firm's Metal Research and Development Building. It will carry on research for these Continental Divisions: Flexible Packaging, now at Mount Vernon, Ohio; Fibre Drum and Corrugated Box, presently at Van Wert, Ohio; Boxboard and Folding Carton, at Uncasville, Conn.; and Bondware, White Cap and Bond Crown, and Plastic Bottle and Tube, all now in Chicago.

*Appointment*

Charles Swerdlove has been named manager of Continental Can's Chicago folding carton plant.

He replaces V. J. Porth, who is retiring after being in the folding carton field since 1911.

**Container Corp. of America**

*Appointments*

Wesley M. Dixon, president, Container Corp., has been named also chairman and chief executive officer of the organization. In the latter post he succeeds the late Walter P. Paepcke, founder of the company, who died April 13 after a brief illness.

Other action taken by the board of directors at the company's annual meeting included: the election of Leo H. Schoenhofen, senior vice-president, as a director; of Harry E. Green, general counsel, as vice-president and general counsel; and of Edward K. Meier as secretary.

*Obituary*

Walter P. Paepcke, chairman of the board and chief executive officer of Container Corp. of America, died Wednesday, April 13, in Billings Hospital after a brief illness. He was 63.

He was buried in Aspen, Colo., a mining town Mr. Paepcke rebuilt into an international cultural and sports center.

Mr. Paepcke is survived by his wife, Elizabeth N. Paepcke; a sister, Mrs. Louis Guenzel, Chicago; and three daughters, Mrs. Anina Paepcke Woods of San Francisco, Mrs. Paula P. Zurcher of Atherton, Calif., and Mrs. Antonia P. DeBrul of New York City.

The Chicago-based company, which he founded in 1926, is the largest manufacturer of paperboard packaging. He was known throughout the packaging, financial, design, and cultural worlds for his innovations and his individualistic ideas.

The major outside interest for which he was best known is the Aspen Institute for Humanistic Studies.

**Diamond Alkali Co.**

*Diamond Merit Scholarships*

In conjunction with the announcement made by The National Merit Scholarship Corp., naming the winners in the nationwide competition, Diamond Alkali Co. announces the winners of the Diamond Merit Scholarships. They are Michael Stephen Pallak and Clifford Joseph Fredricks.

The Diamond Alkali Co. Foundation sponsors two awards in the National Merit Scholarship Awards Program, part of Diamond's fourfold aid to education program. Other aspects of the program include direct grants to various schools, employee gift matching program, and a graduate fellowship program.

**DeZurik Corp.**

*Eccentric Valves Bulletin*

A new 8-page, 2-color bulletin is now available describing DeZurik eccentric valves. The bulletin lists features of the valve as well as materials, pressure ratings, dimensions, an accessories, and outlines the broad areas where the valve i extensively used. For a free copy, contact the DeZuri representative in your area, or write to DeZurik Corp Sartell, Minn., for Bulletin 110.

**E. I. du Pont de Nemours & Co.**

*Appointment*

Arthur G. Pope, sales supervisor for the Western district du Pont's Dyes and Chemicals Division of the Organi Chemicals Dept., has been appointed manager of that distric for the division, effective May 1. At the same time, th division's Western district headquarters will move from Lo Angeles to Palo Alto, Calif.

**Dyestuff and Chemical Div./General Aniline & Film Corp**

*New Sales Engineer*

Frederick W. Morgart, Jr., has joined Antara Chemical a Sales Division of General Aniline & Film Corp., New York N. Y., as sales engineer in charge of Antara field sales in th Minneapolis, Minn., area.

Mr. Morgart currently resides with his family in Mounc Minn., a suburb of Minneapolis. He is a graduate chemica engineer from the University of Minnesota ('47).

**Graver Water Conditioning Co.**

*Appointment*

Joseph H. Duff has been promoted to technical manage Mr. Duff, who has been with Graver for 10 years, was formerl assistant technical manager. He succeeds Mr. Lane whos appointment as head of the company was recently announced A vice-president of the Metropolitan Water and Wast Society, Mr. Duff is also a member of the American Chemic Society and other technical organizations. He is the author several technical papers and articles on aspects of liquid pur fication.

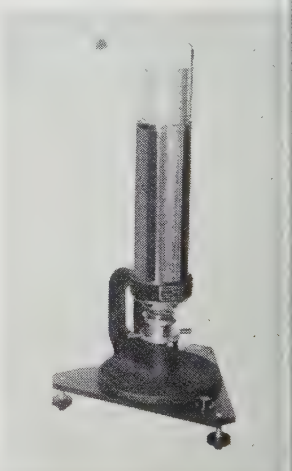
**W. & L. E. Gurley**

*Leveling Base Aids Instrument Use*

A leveling base enabling tests to be run with an instrument which must rest on a variety of surfaces is available from Gurley.

The base can be used with a wide variety of instruments. The legs are three leveling screws, mounted at the corners of a triangular platform. A circular level mounted at one corner of the surface of the platform indicates when an exact level has been achieved.

Details are available from Industrial Division, W. & L. E. Gurley, Troy, N. Y. Write on letterhead.



***Instrument leveling bas supports a Gurley densometer***

**Hercules Powder Co.**

*"Ceron" Water-Soluble Polymers*

The "Ceron" family of water-soluble polymers, useful adhesives, thickeners, protective colloids, and suspendi agents, are described in product data available from Hercule

Ceron is available as a nonionic, anionic, and cation product. In addition, Ceron N, nonionic, is available in thr different types. The polymers are carbohydrates etherified

give water solubility, physical and mechanical properties, and other characteristics desired.

In solution, the Ceron polymers have certain characteristics similar to starches, but they are soluble without cooking and do not retrograde.

Ceron N types are nonionic and have wide utility as thickeners, sizings, and emulsion stabilizers. Ceron N-4S can be used as a water-soluble thermoplastic to produce films which have quick tack, a wide range of adhesion, and which can be heat-sealed as well.

Ceron N-4E, a very low viscosity, low-molecular-weight type is outstanding for its color and color stability, high solids solution, stable viscosity, and film quality. All Ceron N grades can be readily insolubilized with suitable reagents.

Ceron AN is anionic and has aroused special interest as a suspending agent and thickener in emulsion polymerization reactions. Ceron CN, is cationic, utilized in certain emulsifications, and useful in cotton textile processing and in papermaking.

**R. G. LeTourneau, Inc.**

*Electric Powered Log Grapple*

A new type log grapple that is electrically actuated, is now available for use on LeTourneau Electric Powered Log Loaders with either a heel or straight type boom, and on single line fixed crane installations where 220/440-volt power is available.

The model incorporates a small, compact electric motor and gearbox, mounted on the grapple, which actuates the cable mechanism that opens and closes the arms. Power for the grapple motor is supplied from either the main power plant of the loader, or from standard commercial power in the case of fixed crane installations.

More information about the LeTourneau "Electric Powered" Log Grapple is available from R. G. LeTourneau, Inc., 2399 South MacArthur, Longview, Tex.

**Minerals and Chemicals—Philipp Bros, Inc.**

*Triple Merger Proposed*

Charles A. Specht, president of Minerals & Chemicals Corp. of America, and Siegfried Ullmann, president of Philipp Bros., Inc. and chairman of the Board of Philipp Bros. Ore Corp., announce that their respective directors will recommend to their stockholders the merger of the three companies. The merged corporation will be known as Minerals & Chemicals—Philipp Brothers, Inc.

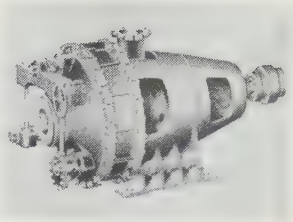
Philipp Brothers, Inc. and its subsidiary, Philipp Brothers Ore Corp., are leading, worldwide importers, exporters, processors, and merchants in ferrous and nonferrous ores, metals, and minerals.

Minerals & Chemicals is a major producer and processor of kaolin, attapulgite, activated bauxite and limestone products, having a variety of industrial applications in a wide number of industries. Mines and plants are located in Arkansas, Florida, Georgia, Michigan, Ohio, and Virginia and a research center at Menlo Park, N. J.

**Morden Machines Co.**

*The Disco-Finer*

A new machine developed by Morden the Disco-Finer, presents a new concept in refiner design.



The Disco-Finer provides exceptional precision and high quality of stock preparation because the new design principle introduces automatically self-aligning rotor and stator plates that remain in perfect parallel relationship. It may be used for either defibering or refining. Conversion is easily made by changing direction of flow and plates. The Disco-Finer is self-pumping and self-pressurizing. A variety of refiner plate designs and materials may be used to obtain desired results.

For full particulars write to Morden Machines Co., 3420 S. W. Macadam Ave., Portland 1, Ore.

**National Lead Co.**

*Baltimore Office for Titanium Pigment*

Titanium Pigment Corp. will open a Baltimore sales office under the supervision of Wyatt Schoonmaker, Middle Atlantic District sales manager. Mr. Schoonmaker, whose office has been in Philadelphia, is well known in the Middle and South Atlantic States, having served this area for approximately 28 years.

**National Starch and Chemical Corp.**

*Resin Gives Top Barrier Properties*

National Starch has announced the perfection of a water-system, latex form of polyvinylidene chloride resin that is highly stable and will, when used as a coating material, impart a much sought-after combination of outstanding barrier and protective properties.

This new material, called Resyn 3600 (trade name to be announced), can be applied at low cost to a variety of porous and nonporous substrates by standard coating equipment. Need for laminating or extrusion operations is therefore eliminated. All the protective properties of polyvinylidene chloride film are completely retained in the final coated surface.

Extensive tests of materials coated with Resyn 3600 have been made and they were found to have an extreme degree of water and grease resistance, chemical inertness, nonflammability and almost total resistance (ranging from 1000 to 2000 times greater than polyethylene) to transmission of carbon dioxide, nitrogen, oxygen, and other common gases. Rate of moisture vapor transmission through these materials is lower than what would be possible with any other known commercial coating.

National is now constructing a special facility at its Meredosia, Ill., plant which, when it goes into production sometime early this fall, will be able to supply some 14 million lb. of the new resin annually. Plans also have been made to expand this capacity to accommodate the expected increase in demand.

*Appointment*

William H. Stone has been appointed Southeastern Division manager for the paper, textile, and food industries with headquarters in Atlanta.

Mr. Stone will make his headquarters at National's office, 87 Haynes St., N. W., Atlanta, Ga.

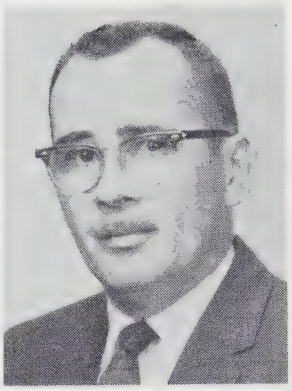
*William H. Stone*

**Nichols Engineering and Research Corp.**

*Appointment*

Nichols announces the appointment of Thomas E. Davy as manager of its Filtration Division. Mr. Davy previously was secretary and manager of the Customer Service Dept. of Komline-Sanderson Engineering Corp

In his work with Nichols, Mr. Davy will deal with both municipal and industrial waste applications.

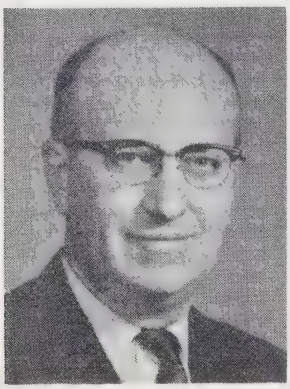


***Thomas E. Davy***

**Pandia Division/The Black-Clawson Co.**

*Appointments*

The appointment of Theodore Detcher and William Herbert to positions with the Pandia Division of Black-Clawson was announced by Carl C. Landegger, administrative vice-president of the company.



***Theodore Detcher***

***William Herbert***

Mr. Detcher will serve as assistant sales manager and Mr. Herbert as assistant chief engineer for the Pandia Division, manufacturers of the Black-Clawson line of pulp mill equipment.

**Raybestos-Manhatten, Inc.**

*Manhattan Roll Seminar at Beloit College*

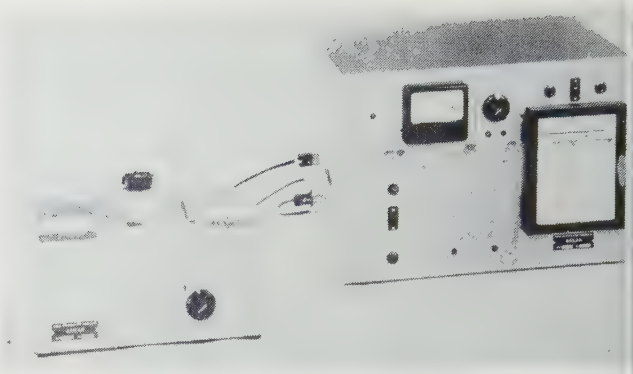
In cooperation with Beloit Iron Works, the Manhattan Division of Raybestos-Manhattan, Inc., conducted a roll seminar at Beloit College on April 12. Its purpose was to provide a broader understanding of the newer techniques and materials in the manufacture of rubber covered rolls used by the paper industry.

Papers read were: "Manufacture of Rubber Covered Rolls," by E. D. Hines; "Compounding for Roll Coverings," by R. L. Holmes; "Nip Widths of Rubber Covered Rolls," by A. W. Beucker; "Top Press Roll Coverings," by J. J. Connors; "Research and Development at Manhattan," by C. P. McHugh. Discussion panel members were: A. A. Campbell, A. F. Kuehn, Jr., J. W. Degnan, H. E. Chew, H. D. Jones.

**Robbins Instrument Co., Inc.**

*Arkas (Bendtsen) Thickness Tester*

This instrument continuously measures, under preselected constant pressure, a $2^3/_4$-in. wide sample strip (generally a strip across the complete roll). Variations in thickness are accurate to 0.001 mm. The recorder produces a true thickness profile in a matter of 4 to 5 min. after the paper has been made.



***Arkas (Bendtsen) thickness tester***

The Arkas (Bendtsen) tester is distributed through Robbins Instrument Co., 110 West 30th St., New York 1, N. Y.

**J. O. Ross Engineering Div./Midland-Ross Corp.**

*S. W. Fletcher Retires*

Saxton W. Fletcher has retired as president of J. O. Ross Engineering Division.

Mr. Fletcher, a graduate of Harvard and the Massachusetts Institute of Technology, started with Ross Engineering in 1923, joining his friends J. O. Ross, A. B. Clark, and F. W. Partsch as the founders of the company. His duties will now be handled by the executive vice-president of Midland-Ross, Chester J. Schmidt.

***Saxton W. Fletcher***

**Sandoz, Inc.**

*Appointment*

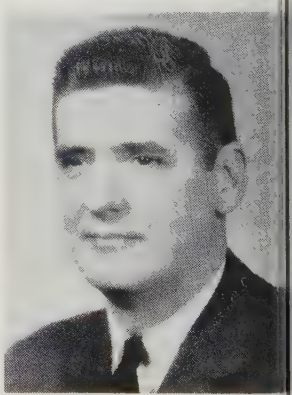
Richard Cobden has been appointed chief chemist of the paper department, Sandoz, Inc., dyestuff and chemical manufacturers.

**The Stanley Chemical Co.**

*Appointment*

William G. West has been appointed sales manager of The Stanley Chemical Co., subsidiary of The Stanley Works, East Berlin, Conn.

Mr. West comes to Stanley from The Borden Chemical Co., New York City, where he had been general sales manager since 1956. Previously he was director of sales, plastics division of the Celanese Corp. of America, Newark, N. J.



***William G. West***

**Shuler and Benninghofen Co.**

*Obituary*

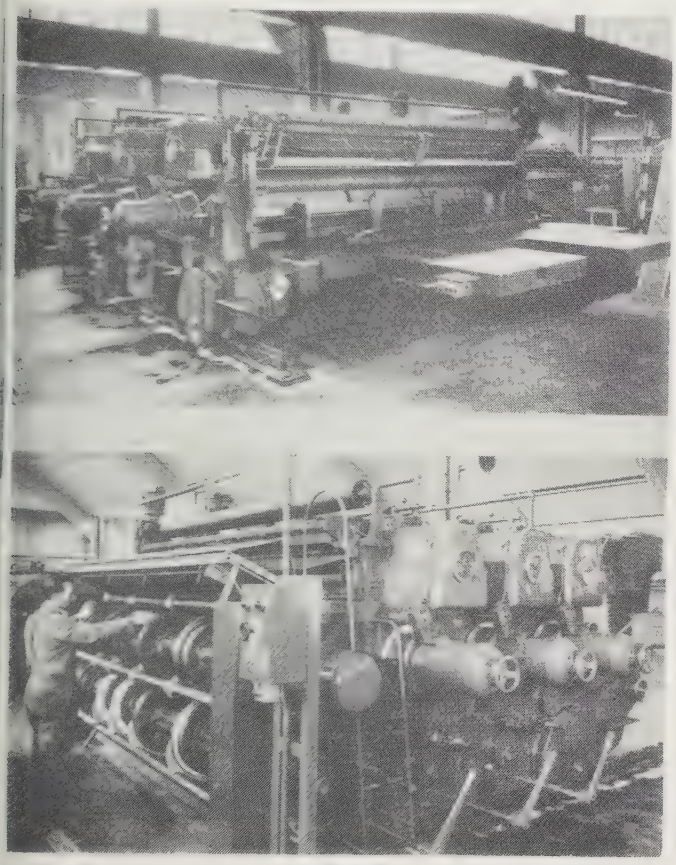
Sidney J. Whelen, 73, who was a top salesman for many years for Shuler & Benninghofen, Hamilton, Ohio, died April 21 at his home at 2310 Jefferson Ave., Norwood, Ohio. He is survived by one son.

Mr. Whelen covered Pennsylvania, New Jersey, Virginia, Maryland, and North Carolina for Shuler & Benninghofen until his retirement in 1952.

**Henry Simon, Ltd.**

*Giant Three-color Printer Slotter*

The biggest multicolor printer slotter outside America—probably the biggest in the world—has been installed at Zewa Faltkistenwerk, Mannheim/Rheinau, Germany. It was made and installed by Henry Simon, Ltd., Stockport, England, manufacturers of the Simon-Hooper range of corrugated container machinery. The new machine prints in three colors at one pass and handles corrugated fiberboard sheets up to 60 × 140 in., or a maximum of 75 × 140 in. when the skip feed is employed. It slots, creases, and prints up to 160 sheets a minute and is equipped for die-cutting. The total weight is nearly 40 tons.



***The views are taken from (above) the feed end with the machine opened for setting up and (below) the delivery end with the machine closed for operation***

**Testing Machines, Inc.**

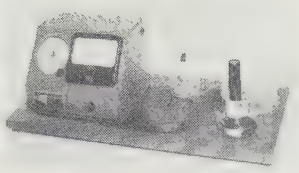
*Automatic KBB Sizing Tester*

The automatic KBB sizing tester was developed as an improved apparatus for simple, accurate measurements of the resistance of paper to waters—It employs a galvanic circuit formed by a zinc plate, the specimen and a sintered bronze electrode. A paper specimen placed between the zinc and bronze electrodes acts as a resistance which decreases gradually as water is exuded from the porous bronze electrode and penetrates the sample. The time in seconds for the indicator needle to reach the end point is recorded automatically.

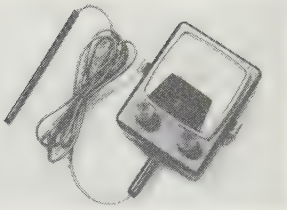
For complete details write to Testing Machines, Inc., 72 Jericho Turnpike, Mineola, N. Y.

*The Thermi-Tem*

A new instrument to quickly and accurately measure temperature of liquids, penetrable masses, and surfaces. It tells you the ultimate temperature in 3 to 10 seconds with an accuracy of 2%. Temperature scales are linear and available as low as −50°F. or as high as 500°F. The indicating meter has shock protected mounting in an anodized aluminum case. The probe has a 6-ft lead and can either be straight or have a 90° angle.



***The automatic KBB sizing tester***



***The Thermi-Term***

Further details are available from Testing Machines, Inc., 72 Jericho Turnpike, Mineola, N. Y.

**Valley Iron Works Corp.**

*Appointments*

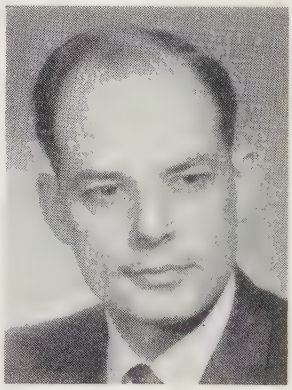
George Reynolds, chief engineer of the Valley Iron Works, announced the appointments of J. T. Strachowski, Howard K. Ainsworth, and O. N. Ellman, Jr., as staff engineers.

**Wisconsin Wire Works**

*Appointment*

William N. Dreyer has been appointed works manager of Wisconsin Wire Works, Appleton, Wis.

Mr. Dreyer has been associated with the company as an engineer for about a year. Prior to this, he served as Professional Engineer with the Bolta Products Division of General Tire and Rubber Co. and specialized in the development of synthetic filaments. In this capacity Mr. Dreyer set up the Synthetic Filament Division of the company and was appointed its industrial engineering manager.



***William N. Dreyer***

# OBITUARY

## Howard D. Meincke

Howard D. Meincke, Chairman of the Board of A. M. Meincke & Son, Inc., Skokie, Ill., died at Evanston Hospital, Evanston, Ill., on March 8, 1960. Mr. Meincke had long been associated with the paper industry. He was 66 years of age and had operated A. M. Meincke & Son, Inc., about 35 years, supplying various types of chemicals for the manufacture of paper. He was also connected with the Whitaker Paper Co. of Chicago and the International Paper Co. The firm of A. M. Meincke Co. dated back to 1906 having been organized in Boston, Mass. Mr. Meincke also operated and owned the Howard D. Meincke Co. supplying clay to the paper industry.

# TAPPI DIVISIONS AND COMMITTEES

*Reports of Activities*

## *Engineering Division*

### *Fluid Mechanics Committee*

The Fluid Mechanics Committee, Engineering Division, met in Room E of the Commodore Hotel, New York, on Feb. 24, 1960, at 12:15 p.m. for a luncheon meeting with C. A. Lee, chairman, presiding.

The following members were present:

G. Bugliarello, Carnegie Institute of Technology
L. A. Burnham, Procter & Gamble Co.
G. L. Calehuff, West Virginia Pulp & Paper Co.
F. R. Forrest, Allis-Chalmers Manufacturing Co.
W. L. Ingmanson, The Institute of Paper Chemistry
R. M. Jodrey, Rice Barton Corp.
K. B. Latimer, Time, Inc.
C. A. Lee, Formex Co.
J. B. Lyall, Armstrong Cork Co.
K. J. Mackenzie, Eastman Kodak Co.
J. Mardon, Anglo Paper Products, Ltd.
S. G. Mason, Pulp & Paper Research Institute of Canada
L. A. Moore, Black-Clawson Co.
J. D. Parker, Beloit Iron Works
N. Shoumatoff, West Virginia Pulp & Paper Co.
J. A. Smith, Clark & Vicario Corp.
A. C. Spengos, Scott Paper Co.
R. Swenson, St. Regis Paper Co.

Present also were the following guests of the Committee:

J. A. Murphy, International Paper Co.
A. H. Nissan, Rensselaer Polytechnic Institute
N. Reitzel, West Virginia Pulp & Paper Co.
J. C. Stewart, Clark & Vicario Corp.

The chairman opened the meeting by introducing the various guests to the members present.

Mr. Smith read the minutes of the last meeting of the Fluid Mechanics Committee at Pittsburgh, Pa., on Oct. 13, 1959, which minutes were approved unanimously without changes.

There then followed reports by the subcommittee chairmen on the activities of the various subcommittees.

Dr. Mason, as chairman of the Subcommittee on Dilute Fiber Suspensions, reported that the proposal for continuation of Research Project No. 172 at Massachusetts Institute of Technology on "Turbulent Transfer Mechanics with Neutrally Buoyant Suspensions" had been approved in the amount of $17,750. This work will continue under the supervision of Professors Ippen and Daily with the study being conducted by a new candidate for a doctoral degree inasmuch as Dr. Bugliarello has received his degree and is now teaching at the Carnegie Institute of Technology. Dr. Mason proposed a meeting at M.I.T. in the fall of 1960 after the new investigators have had an opportunity to become oriented in the problem.

Dr. Mason indicated that it might be inadvisable to publish at present a monograph on the work conducted to date at M.I.T. and suggested that this might be subsequently developed by members of the committee rather than by personnel at M.I.T.

With respect to reports covering the results obtained thus far under prior grants under the auspices of the Subcommittee on Dilute Fiber Suspensions, Mr. Lee pointed out that such reports will be available after publication in *Tappi*. Dr. Mason has suggested to Professor Daily that these reports be published as a series of papers in *Tappi* and also recommends they be published simultaneously in professional journals so as to reach individuals on a scientific level inside and outside of the pulp and paper industry. By this means the interest of professional people in the fluid mechanics field would be further focused on the work conducted under TAPPI auspices.

In response to a question by Dr. Ingmanson as to whether the idea of a monograph had been completely abandoned, Mr. Lee stated that it had not, but that it was perhaps best to allow investigators at M.I.T. to focus on research, with work of editorial compilation and writing of reports by others. The subject of how such a monograph might best be compiled is of interest to all committee members and could be the subject of intensive study.

Mr. Lyall suggested the possibility of publishing these reports in a series of papers in *Tappi* be discussed with the TAPPI Editorial Board. The chairman agreed that this would be done.

To date, according to Dr. Bugliarello, two such papers have been published, one in *Tappi* and the second in the *Journal of Industrial Chemistry*. He also reported that Professor Daily has in mind three additional papers, one in the laminar field and two covering flows in the turbulent region. These would constitute the series of papers referred to by Dr. Mason.

Mr. Lyall moved that the recommendation of the Subcommittee on Dilute Fiber Suspensions with respect to the publication of the M.I.T. reports be approved. The motion was carried unanimously.

Further discussion of the subject ensued with Messrs. Mason, Mackenzie, and Mardon participating. The following points were evolved. Dr. Mason referred to the importance of allowing researchers to report in their own manner and in the professional journals in their fields. He said that papers published in *Tappi* do not necessarily become known to specialists in the field of fluid mechanics because in the usual library indexing *Tappi* is classified under the field of "Pulp and Paper Technology" rather than "Fluid Mechanics." Mr. Mardon suggested that simplification of the overall scope and results of research projects was sometimes necessary and that this could best be accomplished by others than the original investigators. It was Mr. Mackenzie's opinion that most paper companies today have a sufficient number of scientific level personnel to understand both the basic fundamental reporting on a professional level as well as a more popularized version. It was concluded reports might be published in both mediums, with *Tappi* having priority with respect to time, as this is the established policy of TAPPI Engineering Division. Dr. Nissan mentioned that he was especially interested in the subject as he was to present a prepared talk on it the next evening.

Mr. Mackenzie, as Chairman of the Subcommittee on Pipe Friction, then reported the recent activities of his group. There has been a widespread endeavor to increase the use of the shear tester among paper companies as a result of a subcommittee meeting at Pittsburgh following the Engineering Division meeting in October. His subcommittee proposes that a young engineer be hired who, after preliminary training, would visit the various paper mills to acquaint them with the use of the shear tester on pulp slurries. The expense of such a program would be shared by the centrifugal pump manu-

facturers whose representatives on the committee had indicated their support. This support was estimated to be 50% of the total cost. The latter was estimated at $10,000 of which a TAPPI grant would be required in the sum of half this amount. Mr. Lee pointed out that request for such a grant to be effective this year must be submitted to the Research Appropriations Group by April 1. Mr. Lyall pointed out that the program seemed to fit in with the TAPPI Executive Committee recommendations regarding the support of research programs by TAPPI corporate members.

On a motion by Mr. Mardon a vote of confidence in this program by the Subcommittee on Pipe Friction was made and approved unanimously.

Dr. Nissan discussed the relative historical positions of fluid mechanics and hydraulics from the standpoint of courses as they are defined and taught in our universities and pointed out the desirability of a marriage of these subjects in considering any program of research in either field.

In the absence of Mr. Wrist, chairman of the Subcommittee on High Speed Free Surface Flows, Mr. Spengos reviewed this program at the request of the chairman. Mr. Spengos read the Minutes of the meeting of this subcommittee on Feb. 4, 1960, at the University of Michigan in Ann Arbor, Mich. At this meeting Mr. Spengos was appointed the vice-chairman and Mr. Lamb, secretary of the subcommittee. The subcommittee is requesting a TAPPI Research Appropriation Grant in the amount of $14,500 to continue the work under Project Grant No. 156 at the University of Michigan on the subject of free surface flows.

Mr. Shoumatoff mentioned that this report was quite encouraging and proposed a motion to approve this request which would involve the further participation of Dr. C. S. Yih who is now at Cambridge University, England. Further benefits would be derived from Dr. Yih's current association with Professor Taylor in allied work in this field.

Mr. Lee then announced the formation recently of a new Subcommittee on Flow Through Porous Media with Dr. Ingmanson as chairman. Dr. Ingmanson reviewed the program which will be presented under the auspices of the Fluid Mechanics Committee at the forthcoming meeting of the Engineering Division in October, 1960, at Jacksonville, Fla. In addition to the formal papers which have already been approved, it was suggested that an outside speaker who is an authority in the field of fluid mechanics be engaged. In this connection Dr. Mason inquired concerning TAPPI policy with respect to having subcommittee members who are not members of the parent committee nor of TAPPI. Mr. Lee stated that it definitely was TAPPI policy to have such subcommittee members.

Mr. Calehuff, chairman of the Data Sheet Subcommittee, then submitted his report. First, he requested members to submit a list of reference books to which they refer frequently, occasionally, or as a last resort. This information will be compiled by his subcommittee and returned to the Engineering Division Data Sheet Committee. Mr. Calehuff reported that the Data Sheet Review Committee had returned Data Sheets on Stock Friction, No. 205, and Centrifugal Pumps, No. 4, which sheets with a few minor corrections were now satisfactory.

They then ensued a discussion of new committee projects. Mr. Lee mentioned that as the need arose new subcommittees would be instituted in the future to handle such new projects. He said that results of recent questionnaire requesting members to indicate their choice as to subcommittees will be forwarded to the respective committee chairmen so that the latter can then select their membership. Dr. Mason suggested that subcommittee membership be kept within the scope of a convenient sized group for effective contribution.

Mr. Lee stated that the forthcoming technical sessions of the Fluid Mechanics Committee at the Jacksonville meeting in October, 1960, would be on Monday and Wednesday afternoons, October 24 and 26, with a luncheon meeting on Oct. 25.

Papers thus far suggested for this program are as follows:

1. "Creep Response on Wet Pulp Mats Under Compression," by Harry D. Wilder, The Institute of Paper Chemistry.
2. "Drainage in a Rotary Vacuum Former," by S. T. Han, The Institute of Paper Chemistry.
3. "Resistance of Wire Screens to Flow of Water," by W. L. Ingmanson, S. T. Han, and W. T. Myers, The Institute of Paper Chemistry.
4. "Unsteady Flow Due to Wire Shake," by A. C. Spengos, Scott Paper Co.
5. "Operation of FLO-VAC Rotary Type Suction Box," by V. C. Hill and C. L. Clark, Clark & Vicario Corp.
6. "A Final Report on TAPPI Project No. 156—Free Surface Instability," by C. S. Yih and W. R. Debler, University of Michigan.
7. Paper by an authority in field of Fluid Flows.

Mr. Mackenzie indicated paper covering data on "Friction Loss through Pipe Fittings" might not be completed until July or August, but could constitute a short informal paper. Dr. Mason indicated that Professor Daily could give a final report, but would prefer not to request this as no meeting of his subcommittee is contemplated until the fall of 1960. The committee agreed with this suggestion.

Mr. Lee pointed out that the committee should be prepared at the fall meeting to define papers for presentation in 1961 to be in accord with Engineering Division policy requesting committees to have definite commitments on papers by that time.

Under the subject of new business Dr. Mason referred to a forthcoming meeting at Oxford University on Sept. 24 and 29, 1961, on the subject of "Effect of Papermaking Variables on Paper Properties." This meeting will focus on various aspects of fluid mechanics as applied to the papermaking process. Individuals interested in attending this conference may contact Hector W. Emerton of the Albert E. Reed Co., Aylesford Maidstone, Kent, England.

Mr. Mardon then presented an excellent high-speed moving picture of the flow of stock on the wire on newsprint machines which was of great interest. This was concerned primarily with spouting and ridge formation and their causes and corrective measures to reduce their detrimental effects in the finished sheet. These pictures had not previously been presented in the United States or Canada but had been presented by Mr. Mardon abroad during his recent visit to Finland.

The meeting was adjourned at 2:35 p.m.

J. A. Smith, *Secretary*

## *Pulp Manufacture Division*

### *Mechanical Pulping Committee*

The Mechanical Pulping Committee met at the Commodore Hotel, New York, N. Y. on Feb. 22, 1960, at 2:00 p.m.

Present:
J. K. Kirkpatrick, *Chairman*, Bowaters Southern Paper Corp.
S. R. Parsons, *first vice-chairman*, Consolidated Water Power and Paper Co.
Maung Shwe Htoo, *second vice-chairman*, International Paper Co.
J. H. Perry, *Secretary*, Norton Co.
Christian Anker, Aktieselskapet Risor Traemassefabriker, Risor, Norway
Piero Bersano, Cartiere Burgo, Turin, Italy
M. A. Burnston, TAPPI
H. A. Dailey, Diamond-National Corp.
Thomas Gerace, St. Regis Paper Co.
J. F. Jahne, Diamond-National Corp.
E. H. Johnson, Stevens & Thompson Paper Co.
R. A. Joss, Technical Section, CPPA
T. F. LaHaise, Ryegate Paper Co.
W. H. McPherson, Minnesota and Ontario Paper Co.
F. W. O'Neil, State College of Forestry, New York
K. L. Pingrey, Diamond-National Corp.
H. P. Waldenmyer, Oxford Paper Co.
J. H. White, Keyes Fibre Co.
A. J. Winchester, TAPPI
A. A. Yankowski, Kimberly-Clark Corp.

*Mechanical Pulping Committee*

*Groundwood Manual (Monograph No. 21) Committee meeting*

Mr. Kirkpatrick, chairman, opened the meeting promptly at 2:00 p.m. and requested the secretary to read the minutes of the last meeting of October 5. The motion was made by John H. White and seconded by K. L. Pingrey that the minutes be approved as read. This was carried.

Mention was made that the interim project reports submitted by several members had not been published in TAPPI as was directed in the several previous minutes. The discussion on this subject led to the conclusion that the interim reports should be included in the minutes to insure their publication, if at all possible. However, it will be decided by the committee whether these interim reports will be included in the minutes or be published as a separate report.

The secretary discussed this with Mr. Winchester after the meeting and learned that the interim reports had not been published because no request had been made to the proper officials. Mr. Winchester suggested that the secretary should write a letter to him with the copies of the reports when it is decided that they should be published independently.

S. R. Parsons was complimented by Keith Kirkpatrick for the fine work which he has done relating to the membership attendance at meetings as outlined in our minutes of October 5. Due to these efforts, Mr. Parsons was able to clarify the status of the so-called delinquent members. The results were that in every case there was a justifiable reason for non-attendance and in most cases the member in question had decided to send an alternate when he personally could not attend.

It should be pointed out here that all members can send alternates or can be accompanied by any number of people at any of the committee meetings.

A letter from M. S. Anderson was read by the chairman in which it was stated that Mr. Anderson will remain as a member of the committee and will attend all meetings possible or will appoint an alternate when required.

Fred Bishop submitted his resignation by letter because his duties do not permit attendance on a regular basis. A motion by Earl Johnson, seconded by John White, was made to the effect that Mr. Bishop be asked to remain as a valued member of the committee and that he make all effort possible to send an alternate. This motion was carried unanimously.

A motion by John White, seconded by Tony Yankowski and carried, reads as follows: "Upon the resignation of any member in good standing, he be requested to reconsider or provide an alternate; and if this arrangement is not possible, he would be placed in an advisory capacity and kept posted on committee activities for a period of two years."

It was felt that this would provide the committee with the advantage of their experience for a time and also would permit the individual concerned the opportunity to return to committee activities without formality if he felt that he could again serve.

*Project No. 591—Groundwood Manual*—F. H. Johnson, chairman. Earl Johnson reported that all chapters were now in galley form and were to be reviewed by the respective authors at 3:00 p.m. February 24 in Parlor G at the Commodore Hotel and he further reported that the manual would be published in March of this year. This action completes this project.

*Project No. 636—Effect of Underwater Storage of Pulpwood on Groundwood Brightness*—Karl L. Pingrey, chairman. Karl L. Pingrey reported that the wood samples had become exhausted and also he said that Jim Parsons' samples are all gone. An interim and final report was submitted by Harry Daily, product control supervisor, Diamond-National Corp., Ogdensburg, N. Y. This report was given as a formal paper at the Mechanical Pulping Session at the Forty-fifth Annual Meeting of TAPPI on February 24. This will be published in *Tappi*. Mr. Christian Anker reported that the wood stored in water at his mill in Norway appears to be stratified. The wood which was stored on top of the pile, that is, the wood that was not under water, was harder to bleach than that which was under water. The pulp from the underwater-stored-wood was the brightest and easiest to bleach. All of this wood was partly barked due to the fact that it had been river run. Mr. Anker had concluded that the lower the moisture content the harder to bleach. This project is now considered complete.

*Project No. 678—The Effect of Closed White Water System on Groundwood Brightness*—F. W. O'Neil, chairman. This project was considered closed at our previous meeting but Christian Anker had some further facts to report which he presented to the meeting. Upon motion of J. H. White, seconded by A. A. Yankowski, it was moved that Mr. Anker submit a formal report on his findings in regard to Project No. 678.

*Project No. 680—A Survey of Groundwood Mill Process Instrumentation*—J. K. Kirkpatrick, chairman. There was no report on this project for this meeting but the committee was enlarged to include Piero Bersano, Christian Anker, Bill McPherson, Tom LaHaise, John White, Earl Johnson, Tommy Gerace, and Jim Perry. It was decided that this subcommittee join forces with the instrumentation subcommittee of the Engineering Section. Keith Kirkpatrick will make the necessary arrangements.

*Project No. 779—A Manual Giving Descriptions of the Various Processes of Mechanical Pulping*—J. H. White,

chairman. There was no report at this meeting but Tony Yankowski has promised a full report at the next meeting.

NEW BUSINESS

*Fourth International Mechanical Pulping Conference.* Jim Parsons, program chairman, reported that four regional program chairmen had been appointed and that the plans for programming were well under way, with some most interesting subjects for consideration. He has scheduled a meeting of the Program Committee for June 17, 1960, in Chicago. Officers of the Fourth International Mechanical Pulping Conference are as follows:

General Chairman—W. H. de Montmorency
General Program Chairman—S. R. Parsons
Local Arrangements Chairman—A. A. Yankowski
Publicity Chairman—W. H. Copeland

The regional program chairmen are:

E. P. Walsh—Canada
Karl L. Pingrey—U. S. A.
Neil Robertson—West Coast
George Thompson—Europe

A letter from Maung Shwe Htoo was read in which he tendered his resignation as an officer, but stated the desire to continue to serve on the committee. His resignation was regretfully accepted and a vote of thanks was given him by the committee for the outstanding job that he has done. His wish to serve on the committee was accepted by acclamation. Mr. Htoo explained that he is a candidate for his Ph.D. degree and that time would not permit him to do justice to the office of first vice-chairman.

*Election of Officers.* The resignation of M. S. Htoo left the office of first vice-chairman to be filled and the office of second vice-chairman to be filled by election as provided in our by-laws. J. H. White made a motion that T. F. LaHaise be appointed first vice-chairman. This was seconded by Maung Schwe Htoo and carried. Therefore, T. F. LaHaise will serve as first vice-chairman for this year.

The office of second vice-chairman was not filled at this time because time was running out, so it was decided to carry this over until the next meeting. The office of second vice-chairman is principally concerned with programs and it was thought, inasmuch as the committee was going to devote so much time and effort to the Fourth International Mechanical Pulping Conference, that this election could be deferred until the next meeting.

J. H. Perry was again elected Secretary.

J. K. Kirkpatrick introduced his successor as chairman of the committee, S. R. Parsons, formerly first vice-chairman, as per our bylaws. Mr. Kirkpatrick congratulated Mr. Parsons and joined with the committee in wishing him all success in his office.

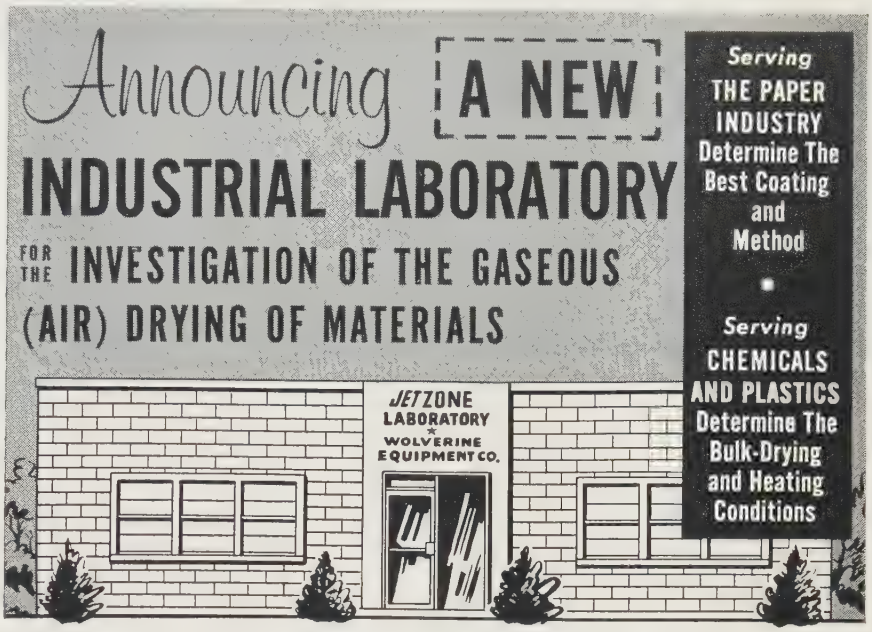
Maung Shwe Htoo initiated a rising vote of thanks to Mr. J. K. Kirkpatrick who so ably filled the office of chairman for the past year. Mr. Kirkpatrick now becomes liaison officer as provided in the bylaws.

It was decided that the next meeting would be held at a mill location, probably in June. One member tentatively invited the group and will clear it with his Management before extending a formal invitation.

The need for new projects is recognized and to that end Keith Kirkpatrick suggested that grinder designs could be improved and Karl Pingrey suggested that better methods of groundwood evaluation would make a suitable project.

The meeting adjourned at 4:45 p.m.

J. H. PERRY, *Secretary*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***Preceded by:*** Coater, impregnating tanks and squeeze rolls.

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***Preceded by:*** Feeder or pelletizer.

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***Preceded by:*** Coaters by different manufacturers.

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# Water Immersion Test of Paperboard

*New Suggested Method T 491 m*

(THIS METHOD IS UNDER THE JURISDICTION OF THE TAPPI PAPERBOARD TESTING COMMITTEE)

This test is applicable to paperboards that are hard sized throughout. The procedure is designed to measure the overall sizing of the board including its resistance to the absorption of water through its cut edges, as well as transversely through its faces. The sizing or water resistance of the faces alone may be measured as described in TAPPI Standard T 441 m.

### APPARATUS

1. *Dish* of sufficient size to hold at least five 6 by 6 in. specimens of paperboard horizontally under 3 in. of water.
2. *Weights* or a piece of $^3/_8$- or $^1/_2$-in. mesh wire screen not more than about twice the weight needed to keep the specimen submerged against the bottom of the dish.
3. *Balance* to weigh the specimens, having a minimum sensitivity of 0.05 g.

### TEST SPECIMEN

Select at least five test specimens which are representative of the shipment and cut them 6 ± $^1/_{32}$ in. (15.25 ± 0.1 cm.) square. Condition them according to TAPPI Standard T 402 m.

### PROCEDURE

Weigh a test specimen to an accuracy of within 0.1 gram. Submerge it in 3 in. (7.6 cm.) of distilled, or equivalent, water in the dish at 23 ± 2°C. (70° to 77°F.) being careful not to trap any air bubbles, and note the time. By placing the weights on two diagonally opposite corners, or by means of the piece of wire screen, hold the specimen 3 ± $^1/_4$ in. beneath the surface of the water. After 10 min. have elapsed, remove the sample and quickly but gently, blot both surfaces and edges with a large soft cloth or the equivalent, to remove any excess water and weigh immediately. Record the increase in weight. Test at least five specimens.

### REPORT

Report the "water immersion number" as the average increase in weight of the conditioned specimens to the nearest 0.1 g. State also the average conditioned weight of the 6 by 6 in. specimens in grams.

# Water Absorption of Paperboard

*New Suggested Method T 492 sm*

(THIS METHOD IS UNDER THE JURISDICTION OF THE TAPPI PAPERBOARD TESTING COMMITTEE)

This method is for the determination of the water absorption properties of an unsized or slack-sized paperboard. It is generally suitable for sheets of paperboard 0.008 in. thick or thicker and may be used to predict their gluing quality.

For testing bibulous paper or materials such as toweling, blotters or beer mat stocks, use TAPPI Standard T 432 m, which specifies the use of a larger drop (0.1-ml.).

### APPARATUS

1. *Buret,* preferably of 25-ml. or less capacity. Adjust the opening in the tip so that when 5.0 ml. of water at 73°F. are discharged, 100 ± 4 drops of water are formed.
2. *Stopwatch* or clock with second hand.

### TEST SPECIMEN

Select at least five representative test specimens for each side to be tested. Mark the wire of felt sides of the specimen and condition them in accordance with TAPPI Standard T 402 m.

### PROCEDURE

Test the specimen in an atmosphere in accordance with T 402 m. Fill the buret with distilled water at a

temperature of 73°F. In turn, place each specimen with the side to be tested uppermost on a level surface situated $^3/_8$ in. (1 cm.) beneath the tip of the buret. Allow 1 drop of water to fall upon the paperboard and record the time in seconds required for the drop to be completely absorbed as indicated by the wet spot losing its gloss.

### REPORT

Report the water absorption as the average time in seconds required for the 0.05-ml. drop of water to be absorbed by the specified side of the paperboard.

### ADDITIONAL INFORMATION

1. For harder sized sheets, TAPPI Standard T 441 m is a preferable test procedure.

2. Board having a 0.05-ml. water drop absorption time of over one min., normally may be glued only with difficulty.

3. One corrugated board plant has found that if the absorption time exceeded 45 sec., difficulty in forming the flutes on the corrugator might be experienced. Another such plant favors a test of about 15 sec. for the corrugating medium and for the unfinished side of the facings.

# Tensile Breaking Strength of Paper and Paperboard

## *Proposed Revision of TAPPI Method T 404 m-50*

**(THIS METHOD IS UNDER THE JURISDICTION OF THE PAPER TESTING COMMITTEE)**

This method is for determining the tensile breaking strength of papers and paperboards. Related methods include TAPPI Standard T 456 m, Wet Tensile Breaking Strength of Paper and Paperboard, and TAPPI Suggested Method T 481 sm, Zero-Span Tensile Strength for determining fiber orientation in paper.

### APPARATUS

*Tensile testing machine*, having the following:

1. Two clamps from $^1/_2$ to 2.0 in. wide (see section on Test Specimen for preferred widths) with clamping surfaces in the same plane parallel to the direction of motion of the applied stress and so aligned that they hold the test specimen in that plane throughout the test without slippage. At the start of the test the edges of the jaws of the clamps are set apart at 180 ±5 mm. (7.1 ±0.2 in.).

*Note:* Many instruments are arranged for an 8-in. jaw separation distance, especially for paperboard and coarse papers; however, the preferred jaw separation at start of test is 180 mm. in all cases. It is usually not difficult to have the instrument changed accordingly.

2. Means for applying a smoothly increasing load to the test specimen until it breaks, the increase being such that additional load applied each second is not different by more than 10% from the additional load applied in the previous second.

*Note:* This condition is fulfilled by most motor driven, tensile breaking strength testers, including the incline plane testers, temperature-compensated spring testers, the usual pendulum type of apparatus, and the constant-rate-of-elongation testers or other instruments, provided that the slope of the stress-strain curve does not change abruptly.

3. Means of indicating the applied load at the instant of rupture, to within ±1%.

### CALIBRATION

Check the apparatus for cleanliness. Then level it accurately in each of the principal directions. Check all the moving parts to ensure that they move freely. Apply various deadweights to the clamp actuating the indicating mechanism and note the scale readings when the weights and mechanism come gently into an equilibrium position from the direction and at the speed (approximately) used in an actual test. In general, each range of the machine should be verified at three or four widely spaced points, and if errors greater than 1% are found, construct a correction curve.

*Note* 1: When calibrating the pendulum type of tester, determine the effect of the friction of the pawls as follows: I. With the pawls engaged as in normal use, allow the calibration weight to exert its force by lowering it gradually by hand at about the speed used in an actual test. Do not drop it, nor lower it too slowly. II. With pawls wedged up with a small piece of paper bent double, gently apply the same calibration weight at the speed to be used and allow the pendulum to come to equilibrium from the same direction as in an actual test. If the reading by I is measurably less than by II, then the friction of the pawls is the more important; therefore calibrate the scale by method I, but first remove any noticeable friction in the pawls. If the reading by I is greater than by II, the friction is less significant than the inertia, therefore calibrate by method II.

*Note* 2: With other types of testers, follow the manufacturer's, and the general instructions given above.

Verify the instrument within 1 month prior to any test.

### TEST SPECIMEN

Obtain the samples in accordance with TAPPI Standards T 400 m and condition them in accordance with TAPPI Standard T 402 m. For each principal direction to be tested, cut at least ten specimen strips with clean and parallel edges to a width within 0.1 mm. of the nominal width, and over 200 mm., preferably 350 mm. (9.9 in.) long. Avoid abnormalities, watermarks, creases, and wrinkles.

For paper, cut the strips preferably 15.0 mm. (0.59 in.) wide. For coarse papers, such as building papers and paperboards over 0.12 in. thick, cut them preferably 1.00 in. (25.4 mm.) wide. In either case, do not cut the test strips less than 0.5 in. nor more than 2.0 in. wide.

*Note:* Varying the width of the test specimen between 0.5 and 2 in. does not, in general, make much difference in the proportionate test results except for unbeaten long-fiber papers, when the difference may be appreciable.

## PROCEDURE

Make the test in an atmosphere conditioned according to TAPPI Standard T 402 m.

Avoid touching the portions of the strips that will be between the jaws. Tightly clamp one end of a test strip in the upper jaw after placing the strip loosely in the lower jaw and checking its alignment. Then tightly clamp the lower end of the specimen and apply the load.

*Note:* Except for a referee test, time may be saved by aligning and clamping the ends of the ten specimen strips together in the upper jaw and breaking them one at a time, after clamping the lower end of each in the lower jaw.

Operate the tester so that the *average* time for the completion of the test will be within 10 ± 5 sec. The appropriate setting of the tester may be determined from a trial test strip, or a table may be prepared giving the approximate settings for a particular type of tester for the width of the specimen and its expected breaking strength and elongation.

*Note:* In cases of dispute, the average time to fracture should be 10 ± 2 sec. Normally the rate of loading is not a very important factor; doubling it usually results in an increase of only about 2%.

Reject readings from individual strips if the strip slips or breaks in or at the edge of the clamps.

Record the result of each individual breaking load to the nearest two or to three significant figures.

Test at least ten strips cut in each principal direction of the paper, unless the strength in one direction only is required.

Compute the average breaking load and, preferably also the standard deviation, for each direction tested.

## REPORT

Report results obtained on strips cut in the machine direction as the tensile strength, machine direction, and on strips cut in the cross direction as the tensile strength, cross direction.

Report the average value of the breaking load calculated either to kg. per 15 mm. or less desirably, to lb. per in. to three significant figures (kg. per 15 mm. × 3.71 = lb. per in.).

A complete report requires, in addition, statements of:

(a) The width of the test specimen.
(b) The distance between the jaws at the start of the test.
(c) The average value of the "time to break" for each principal direction tested.
(d) The number of strips tested in each direction.
(e) The standard deviation for each direction tested.
(f) The type of instrument and speed of operation of the driven head.

*Note:* In a pendulum tester, the speed depends on the scale used and the leverage of the pendulum as well as the rate of movement of the stressing jaw. The speed of operation may be expressed as the average time to break, or, as the average increase of load per second; preferably however, if available, the average extension per second.

## REPRODUCIBILITY

Duplicate determinations of the tensile breaking strength from samples from the same shipment but on different instruments, are expected to agree within 5%.

## ADDITIONAL INFORMATION

1. If a lesser distance between the clamps is employed, a higher test is usual. For papers which have a poor formation, the difference between 100 mm. and the standard distance of 180 mm., may amount to over 10%. Where a length of strip of 180 mm. is not possible, the machine may be adapted to 150 mm. (6 in.), 100 mm. (4 in.), or 50 mm. (2 in.). If the specimen strips are too short for the tester, they may be extended by means of strips of strong, gummed kraft. In any of these deviations from standard, however, the fact should be recorded in a prominent position in the report.

2. The jaw separation distance of 100 mm. is standard for pulp test sheets. The results are calculated to breaking length in meters, based on the moisture-free basis weight of the test sheets in accordance with the formula $B.L. = 20{,}000\ P/3R$ meters; where $P$ is the load in kilograms to break a 15-mm. wide test strip, and $R$ is the moisture-free basis weight in grams per square meter. See TAPPI Standard T 220 m.

3. The main change in this revision is to replace the requirement for the rate of loading from a rather complicated specification to the same time of 10 ± 5 seconds for all papers and paperboards.

4. Related Methods: A.S.T.M., D828; Canadian P.O.P.A., D-6; British P.O.B.M.A., PT12; German V.2.P.C.O.I., V12/57; French A.F.N.O.R, Q03-001.

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**Eleventh**

**Testing Conference**

**TAPPI**

**Pantlind Hotel**

**Grand Rapids, Mich.**

**Sept. 27–29, 1960**

# ROUTINE CONTROL METHODS

## *RC-279. Analysis of Neutral Sulfite Semichemical Liquors*

The purpose of this method is to establish a rapid method for analyzing neutral sulfite semichemical liquor.

### *Equipment*

The equipment and reagents are as follows: 25-ml. pipet, 2-ml. pipet, 3 burets, 0.1 *N* iodine solution, 0.1 *N* sodium thiosulfate, 0.1 *N* sulfuric acid, 0.1 *N* sodium hydroxide, starch indicator, phenolphthalein indicator, distilled water, and 250-ml. Erlenmeyer flask.

### *Procedure*

Pipet 25 ml. of 0.1 *N* iodine solution into an Erlenmeyer flask containing a small amount of distilled water. Measure a few drops of 0.1 *N* sulfuric acid into the flask. Pipet in the 2 ml. of the liquor to be analyzed. Back titrate with 0.1 *N* sodium thiosulfate, using a starch indicator.

Add enough 0.1 *N* sulfuric acid so that the total volume added equals 5 ml. Boil gently for a few minutes using a $2^1/_2$-ft. air condenser; then cool the flask in cold water. Add 2 to 3 drops of phenolphthalein indicator and with a buret add sufficient carbonate-free 0.1 *N* sodium hydroxide to give a pink coloration. Be sure to measure amount of sodium hydroxide used. Back titrate with 0.1 *N* sulfuric acid until pink color disappears.

### *Reporting*

1. Grams/liter ($Na_2SO_3$) = Net milliliters of 0.1 *N* iodine × 3.15.
2. Alkalinity (g.p.l. of $NaHCO_3$) = 4.2 (Total volume of 0.1 *N* iodine + total volume of 0.1 *N* sulfuric acid − volume of 0.1 *N* sodium hydroxide).

This method was contributed by the Forest Products Laboratory, Madison, Wis.

This is a Routine Control Method and should not be considered as a Standard in any way. Corrections may be made before loose-leaf publication. Comments will be welcomed and should be sent to A. J. Winchester, TAPPI, 360 Lexington Ave., New York 17, N. Y.

## *RC-280. Test for Reversion of Bleached Pulp*

The object of this method is to measure quickly the relative brightness reversion of pulp on aging by using heat.

### *Apparatus*

1. A forced air circulating oven that will hold the temperature at 105° ± 2°C.*
2. A wire rack with small hooks to hold pulp handsheets designed to support itself on the shelf brackets inside the oven.

The principal advantage of this method is the speed with which reversions can be run and the reproducibility of the results. The major disadvantage is that the air used in the test is dry, whereas in a bale of pulp there is moisture, and this moisture is a factor in the natural aging or brightness reversion.

### *Procedure*

Duplicate pulp handsheets are made for brightness testing. One sheet is tested for G.E. brightness without fading (Bri.). The second sheet is punched and hung on the rack in a forced air circulating oven for four hours at a temperature of 105°C. There should be no other samples, vessels, etc., in the oven, i.e., this oven should only be running brightness reversion tests.

### *Calculation*

At the end of exactly 4 hr.† the pulp sheet is taken out of the oven and the G.E. brightness read (faded Bri.).

(Initial Bri.) minus (faded Bri.) equals oven-faded brightness loss.

A typical example on a high brightness bleached kraft pulp might read:

87.8 (Bri.) − 83.4 (faded Bri.) = 4.4 oven-faded brightness loss.

* A satisfactory oven is made by the Precision Scientific Co., Cat. No. 1050 model.

† The temperature should be 105°C. to start and the time must be exactly four hours. Longer time means more brightness loss and *less* means less brightness loss.

This is a Routine Control Method and should not be considered as a Standard in any way. Corrections may be made before loose-leaf publication. Comments will be welcomed and should be sent to A. J. Winchester, TAPPI, 360 Lexington Ave., New York 17, N. Y.

## *Binders for RC Methods*

The Routine Control Methods Committee of the Testing Division has sponsored the idea of a loose-leaf binder to contain all the Routine Control Methods. The binder will be similar to that used for the Data Sheets, with three rings and suitably imprinted. The binder will be sold at cost. Orders should be addressed to TAPPI, 360 Lexington Ave., New York 17, N. Y., and accompanied by check or money order. The price of the binder is $1.50 per copy, postpaid.

**Eleventh**

**Testing Conference**

**of the**

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**of the**

**Pulp and Paper Industry**

**Pantlind Hotel**

**Grand Rapids, Mich.**

**Sept. 27–29, 1960**

# LOCAL SECTION ACTIVITIES

## *Meeting Calendar*

***June, 1960***

17–18 Maine-New Hampshire Section, Mountain View House, Whitefield, N. H., Annual Meeting.

21 Kalamazoo Valley Section, Annual Golf Outing, Gull Lake Country Club.

***September, 1960***

12 Eastern District, New England Section, Armand's Beacon Terrace, Framingham, Mass.

15 St. Louis Section, Le Chateau Restaurant, 10405 Clayton Rd., St. Louis County, Mo., "Paper Coatings Based on Cellulose Derivatives and Parlon Film Formers on Paper."

21 Pacific Section, Salem, Ore., "Modernization."

***October, 1960***

7–8 New England Section, joint meeting with Connecticut Valley PIMA, Schine Inn, Chicopee, Mass.

***November, 1960***

14 Eastern District, New England Section, Armand's Beacon Terrace, Framingham, Mass.

17 St. Louis Section, Le Chateau Restaurant, 10405 Clayton Rd., St. Louis County, Mo., "Recent Advances in the Packaging Field," by C. P. Olstad, Crown Zellerbach Corp.

***December, 1960***

5 New England Section, Storrowton Tavern, West Springfield, Mass.

***January, 1961***

9 Eastern District, New England Section, Armand's Beacon Terrace, Framingham, Mass.

***March, 1961***

13 Eastern District, New England Section, Armand's Beacon Terrace, Framingham, Mass.

***April, 1961***

10 New England Section, Storrowton Tavern, West Springfield, Mass., Management Night.

***June, 1961***

8–10 Joint Meeting, New England Section and Maine-New Hampshire Section, Wentworth-by-the-Sea, N. H.

## *Empire State (Central District)*

On March 4, the Central District of the Empire State Section of TAPPI met at the University Club, 431 E. Fayette St., Syracuse, N. Y., with approximately 60 persons present. Dr. Ralph Russell of Syracuse Microbiological Research Center presented the evening's address. His subject was "Practical Aspects of Food Additives Amendment in Regard to Paperwraps."

MARIE M. MARTIN, *Secretary*

### Practical Aspects of Food Additives Amendment in Regard to Paperwraps

*Ralph Russell*

WITHIN a few days, the 1958 Food Additives Amendment to the Federal Food, Drug and Cosmetic Act will become a law. Congress enacted this very important legislation on Sept. 6, 1958, but recognized that industry would time to comply with the regulations set forth in the amendment and therefore, allotted 18 months for this purpose. This period of grace is now over.

There are a few points concerning the law which I have been asked to discuss tonight. I would like to especially help clarify some of the misconceptions that have arisen through misunderstanding of the intent and purpose of the law. Perhaps we can correct some of these misunderstandings during the question and answer period which follows.

The original Food and Drug Act went into effect Jan. 1, 1907. The enactment of this law was the culmination of a long struggle made by the medical profession, and health officials over a long period of years despite strong opposition. Basically, the act provided the general public with protection against misleading or fraudulent claims of certain advertisers particularly those relating to medications claiming the virtues of panacea. This law applied to preparations entering into interstate shipment.

The Act was amended in 1938 to exclude "poisonous or deleterious" substances from foods, regardless of how safe they might be in the amount used, unless such substances were required in the production of foods. Under this amendment industry had no legal responsibility to prove that components of food were safe The burden of proof for determining the safety of a food additive rested upon the Food and Drug Administration.

On Sept. 6, 1958, the 1938 Act was changed by the Food Additives Amendment. Under this amendment the burden of proof that a substance is safe rests upon the food manufacturer. He must now ask the Food and Drug Administration to issue a regulation approving for use in food, of any substance not generally recognized as safe.

Let us examine for a moment some of the reasons why a law such as the 1958 Food Additives Amendment was created. Basically, the law was created because we value life very highly and feel that no one has the right to jeopardize public health or interfer with man's chances for longevity. The Food and Drug Administration is charged with the protection of the general public health.

We have learned a great deal since the 1938 Act, about the cumulative effects of trace amounts of chemicals which may be ingested over long periods of time. We know that even minute doses of a chemical taken over long periods may contribute to public health problems. New chemicals are constantly being introduced to our every day life, which may be harmful to our health. If they are toxic then we may or may not learn to tolerate them. By using new chemicals, we may improve foods, but the effect of these chemicals upon humans may be relatively unknown. The more susceptible human is affected more than the others and standards must be determined upon the possible consumption of a material by this more susceptible person. All of these factors contributed to the enactment of this law.

RALPH RUSSELL, Syracuse Microbiological Research Institute, Syracuse, N. Y.

As soon as we learned that the Food Additives Amendment had been passed, we considered it necessary to prepare ourselves to orient our clients in the paper packaging field, including mills, chemical companies supplying adhesives, sizes, etc., to the responsibilities which we felt would devolve upon them because of this new legislation. We did not feel that it was our responsibility to argue the legal aspects of the law, but to serve industry by advising them whether their products complied with the current interpretations of the law.

The first and most urgent question to be answered was whether the law applied to the products used and manufactured by the paperboard industry since most of our clients were paperboard manufacturers.

We were assured from the very first that the law was applicable to those products of the paperboard industry which were used for the packaging or holding of food to the same extent as to the food itself. The Commissioner made it clear that it would be advisable for industry, and this included the paperboard industry, to undertake immediately the work necessary to obtain data concerning materials used in the production of food packaging products.

We advised our clients of this and for the past 18 months our formerly calm and peaceful existence has been turned into a nightmare of formulation reviews, adjudications, and attempts to clarify one situation before another one was created.

What changes have occurred in the interpretation of the law in the past 18 months and what may we expect tomorrow?

Actually there have *not* been any drastic changes in the FDA.'s interpretation of the law. It has held that if the component substances of a packaging material do not migrate to the packaged food then such substances are not food additives as defined by the Amendment. If, however, any component of the packaging material does migrate into the food then a petition may be required depending upon whether the quantity of such component added to the food is generally recognized as safe or whether a prior sanction or approval exists. Proof of the lack of migration was required regardless of whether barriers were present which could reasonably be expected to prevent possible migration.

Some of you may be interested in the types of situations which we have dealt with and the manner in which these problems are resolved by our laboratory.

We have been called upon to determine the status under the Amendment, of many different items used in the food packaging field. Examples of the type of items we have reviewed would include adhesives and coating formulations, pulping and papermaking chemicals of all types, and the finished packaging items, both paper and plastic.

In reviewing any of these items, the method used to determine their safety or acceptability under the Food Additives Amendment follows a common pattern. The data concerning usage, chemical composition, and toxicity are obtained and examined. In adjudicating paperboard or paperboard containers each component is reviewed and any component not given prior clearance or which cannot be generally recognized as safe must be further studied to determine the occurrence of any migration of the component from the package to the extracting medium. If it is determined that no migration of the chemical in question does occur then no further problem exists since the chemical is no longer subject to the amendment.

When migration is detected and the amount of migration determined, the safety of the components, under the conditions of its intended use must be established in accordance with recognized procedures. This may involve animal studies.

The attitude of the FDA is more realistic today than it was even a few months ago. You are all probably aware of the work that the APPA and the NPA has been doing during the past year to assist in clarifying the position of papermaking chemicals and the fibrous furnishes, wastepapers or otherwise, for use in the manufacture of paper food packaging materials. The status of many of the chemicals has now been made clear in the March 1 Federal Register. The status of the fibrous furnishes, in so far as the use of scrap or waste furnishes is concerned, was made clear in Mr. Larricks' letter to Mr. Luhrs of the National Paperboard Association, in which he states in part:

Already questions have arisen on the part of some members of industry over the interpretation of Mr. Larrick's statements. For example, what constitutes an impervious barrier? An impervious barrier is one which prevents the movement of oil soluble substances from the packaging material to the food. It was the feeling of FDA that the water soluble substances are washed out in normal mill operations. This formed the basis for their reasoning of giving clearance for the use of scrap paper for the direct packaging of dry foods. However, the FDA felt that more information was necessary concerning the possible migration of oil soluble substances in paper packagings items before they could make a ruling on the use of waste furnishes for the direct packaging of an oil soluble food.

> "We regard the use of scrap or wastepaper in making food containers as appropriate when good manufacturing practice is followed subject to the following:
>
> "1. Such containers are suitable for all food package uses where there is an impervious coating or liner between the food and the material made with the scrap.
>
> "2. On the basis of data now available, such containers are suitable for use in direct contact with dry foods which are not fatty foods."

Another question which has arisen concerns the interpretation of the term "fatty food." A reasonable definition of a "fatty" food would be a food which will not, under normal conditions of use, "grease print" the board or set up a mode of migration between the board and the food, for the transfer of oil soluble substances. If migration does occur under these conditions, the material migrating, must, of course, be harmful or alter the characteristics of the food before it can be considered within the legal interpretation of the Food Additives Amendment.

The list of cleared and extended chemicals, which appeared in the March 1, 1960, Federal Register, and Mr. Larrick's letter to industry concerning the use of wastes be considered as an authorization from the government for industry to relax.

There were two purposes behind these latest releases from Washington: (1) it gives the government time to evaluate the situation more thoroughly, (2) it also gives industry the opportunity to determine the status of many of their products.

I believe everyone will agree that the March 6 deadline is not the "bugaboo" that everyone thought it would be. The government has indicated to us many times that they only expect industry to expend a reasonable amount of effort, to correct a situation which FDA feels should be corrected. "They are not going to expect the impossible and they intend to use the rule of reason."

Presented at the meeting of the Central District of the Empire State Section of TAPPI, held in Syracuse, N. Y., March 4, 1960.

## *Empire State (Northern District)*

### Optical Brighteners in the Paper Industry

*Hans Seifert*

FOUR to five million dollars!! That is the amount of optical brighteners the paper industry consumes annually. This information is based on reliable trade reports. I would say that these figures are rather conservative and can easily be doubled by the end of 1960.

Why is the paper industry utilizing optical brighteners?

Hans Seifert, Sandoz, Inc., New York, N. Y.

Brighteners have been on the market for years but it was not until 1946 that the textile industries took them up. The competitive situation forced them to follow the trend after a few pioneers tried brighteners in the cotton knit field. Now, there is hardly any fabric, natural or synthetic, that doesn't contain some. Another reason, the soap industry had taken up brighteners and had educated the general public via television and radio that whiteness is synonymous with cleanliness. The paper industry until recently was a seller's market. They were not interested in any additive that was going to cost them additional money.

It is logical to assume, now that full production has been reached, that there is a lot of interest in new ideas for better paper. There seems to be a tremendous enthusiasm generated at all levels of the paper industry for that whiter than white look. It improves the legibility of writing papers; illustrations are crisper and sharper. It gives new dimensions to printing grades. Ordinary whites are gray by comparison with paper containing brighteners and no longer provide the needed sales stimulus.

There are several ways of obtaining a relatively pure white.

1. The elimination of naturally yellow or brown-colored impurities by solubilizing with various chemicals and subsequent bleaching with commercial bleaching agents.
2. Compensation of any remaining yellow tint by an addition of blue dyestuff. The reflectance is thus distributed more evenly over the spectral range. Although there is a certain loss of clarity and brightness, the yellow tint is simply replaced by a gray one.
3. Introduction of white pigments into the paper. These sometimes display a very high reflectance and due to their high refraction they reduce transparency of the paper and reduce the yellow tint with a certain "diluting" power. True compensation of the yellowness does not occur by adding white pigments.

The following white pigments are used:

Al and Mg silicate; kaolin (Chinaclay), Talcum Ca and Ba sulfate; gypsum, barium sulfate, Mg carbonate (Magnesite), chalk, metal oxide; titanium dioxide.

4. Application of the so-called brighteners. These cover the yellow tint, not by "subtraction" as when bluing, but by replacing the missing reflectance or the blue with additional light originating in their fluorescence. By using brighteners in combination with the best raw materials it is possible to produce white paper of brilliance unobtainable by any other method.

There are a number of brands of brighteners being sold to the paper industry. Among those are: the Blancophors, the Calcofluors, the Paper Whites, and, of course, the Leucophors.

### FUNCTION AND EFFECT OF THE OPTICAL BRIGHTENER

With the ever increasing use of brighteners, more and more people are becoming informed in the way brighteners work. The shortest and most widespread explanation is content to state that the invisible portion of daylight—ultraviolet rays—is transformed into visible light.

In the radiant energy spectrum of the sun approximately 40% of the sun's radiation comes to us as visible light with a wavelength of 380 to 760 mμ, 5% reaches us in the form of invisible ultraviolet rays, and the rest, approximately 55%, is shortwave infrared radiation, commonly known as heat.

The effect of brighteners is based on their ability to make use of that 5% invisible radiation. A brightener absorbs ultraviolet rays. It has the capability to increase its wavelength into the visible region and then re-emit it, primarily as blue light. Thus, it increases the apparent total reflectance of any suitable object which has been properly treated.

This simplified way of looking at things is correct, but it doesn't really go far enough. In order to understand the special characteristics of brighteners it is necessary to enlarge on this simple statement:

As stated previously the chemical compounds under discussion have the property of absorbing ultraviolet rays, which are invisible to the naked eye. This energy gain stimulates the molecule, and as far as the case under discussion is concerned, re-emission of the absorbed light takes place in a form less rich in energy (that is, in long wavelength energy) and in the incredibly short space of time of $10^{-8}$ sec. It is in this practically instantaneous re-emission that fluorescence differs from phosphorescence, in which the duration of the stimulated condition is measurable in seconds and minutes. It might be said that the main characteristic of the low energy light, visible to the naked eye and emitted as a relatively wide band, is its color tint, which can be anywhere between violet and blue-green, depending on the properties of the product. There are many differences in shade of fluorescence from one brand to another.

It seems reasonable that the difference between the absorbed short-wave and the emitted long-wave energy (which is of lower total value) should somehow make itself felt in the maintenance of an energy balance. In the simplest case this takes place in the emission of heat; i.e., very long-wave energy.

The energy emitted can also be of chemical nature. When one considers that the brightener has such a complicated structure, it is not surprising that the stimulated molecules can be particularly sensitive to outside influence in the molecular field, and it is understandable that the splitting up of absorbed energy can also lead to chemical change. The unsatisfactory light fastness of the optical brightener is thus explained, at least in part. When considering light fastness it should not be forgotten that the "depth of color" of a brightener is often very slight—around 0.1% or less. In such weak shades, even the fastest dyestuffs do not exhibit a degree of light fastness in keeping with advertised fastness. However, the so-called "shelf life" or aging properties are no worse than the pulp and additives that may be used.

### FLUORESCENCE INTENSITY

The effectiveness of a brightener is directly dependent on whether the light source contains a sufficiently high proportion of ultraviolet rays. Ordinary incandescent light bulbs do not fulfill the requirements very well, so that brightening is not very discernible. Other artificial light sources, e.g., fluorescent lighting, show up the effectiveness of brighteners quite strongly—depending on the color temperature of the light they supply, which in turn depends on which type of luminous coating has been used. In daylight the effect of brightening shows up very clearly. It must be remarked that visible brightness is in direct relation to the composition of the light, as affected not only by the time of day or season of the year, but also by climate and weather conditions, all of which may influence judgment of the effect.

### MEASUREMENT

Visual evaluation thus becomes difficult, because of the varying conditions under which it is made, but measuring instruments which permit an objective determination of fluorescence have been in existence for several years. It is possible with a relatively modest outlay to measure intensity of fluorescence with more than enough exactitude.

There are two different types of instruments in use. They are reflectance meters, or so-called brightness testers, on one hand and fluorescence meters on the other. The fact that three different types of reflectance meters are used, has given cause to some confusion. On some of these instruments, the effect of brighteners cannot be measured, and on others, only to a varying degree.

In a regular reflectance meter reflectance or luminosity is commonly defined as the grading an observer would assign to an object when comparing it with a scale of gray shades ranging from black to white. The human eye has its greatest sensitivity in the green region of the spectrum. The use of a green filter in the instrument makes the response of the photo-

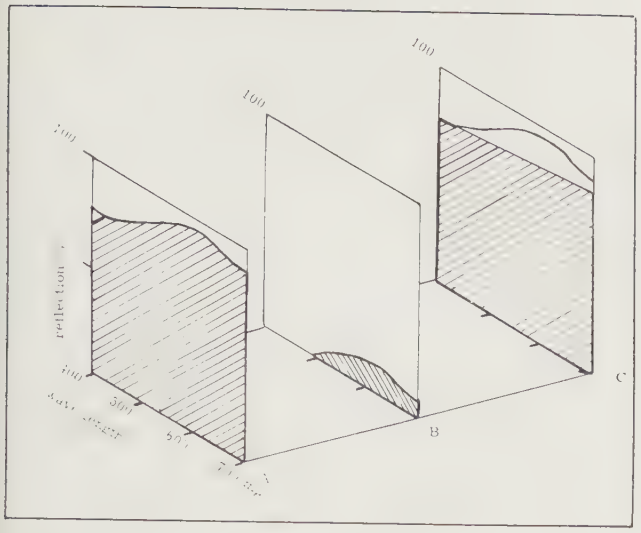


*Fig. 1*

cell equal to the spectral sensitivity of the eye. Without going further into details, the main thing to note in this case is the fact that the green filter removes all ultraviolet rays from the incident beam. No ultraviolet rays can reach the object; there is no chance for a brighteners to act. Measurements on this type of instrument, therefore, will not be affected by the presence of brighteners.

Fortunately, the paper industry has a somewhat different definition of brightness. They have defined brightness as "reflectance in the blue region of the spectrum." This is a brightness tester built in accordance with specifications put up by TAPPI. (Standards T 217 m-48) (Brightness of Pulp) and T 452 m-48 (Brightness of Paper) of the Technical Association of the Pulp and Paper Industry, as well as ASTM Method E 97–53 T for Blue-Light Reflectance (Brightness of Paper).

In order to measure blue light only, a blue filter, passing a waveband of 457 $\mu$, is inserted into the reflected beam and the ultraviolet rays present in the incident beam hit the object. If a brightener is present, the ultraviolet rays are converted and the re-emitted blue visible light passes through the filter and hits the photocell. Therefore, on this type of instrument, brighteners will register and show an increase in brightness. Instruments of this type are built by General Electric, Photovolt and Gardner; lately Hunter has a new instrument.

Some paper mills use another type of instrument. This is a regular reflectance meter converted for use on paper. The green filter simply has been replaced by a blue filter. Examples of this type of instrument are sold by Bausch &

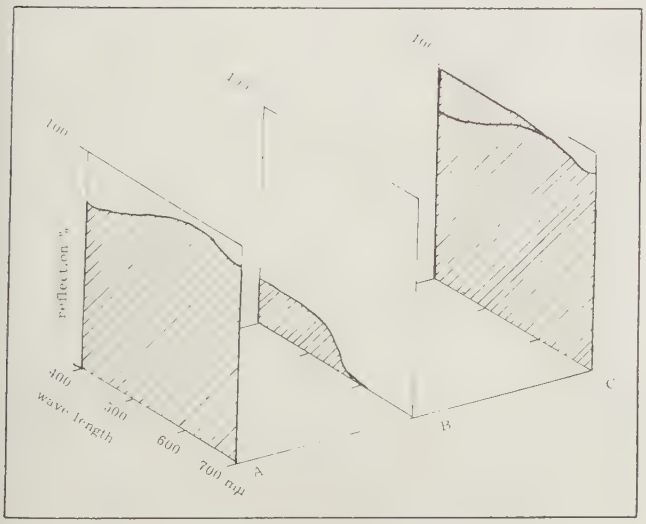


*Fig. 2*

Lomb, Hunter, and Allegheny Instrument Co. They work fine as long as there are no brighteners present. However, again, the blue filter in the incident beam removes all black light. No ultraviolet rays reach the object and therefore brighteners do not register.

An entirely different type of instrument is a fluorescence meter. Here we do not measure the brightness of the object but merely the effect of fluorescent matter present on the object. A black filter removes all traces of visible light in the incident beam. Only ultraviolet rays hit the sample. A part of these ultraviolet rays are converted to visible light and re-emitted, together with some reflected ultraviolet radiation. A gelatin filter removes the ultraviolet portion of the reflected light and only visible light created by fluorescence can reach the photocell.

In this way this instrument can be utilized to control and measure with exactitude the effectiveness of a brightener under varied mill and laboratory conditions. Since all brighteners do not show their maximum response to the same wavelength of ultraviolet light, the method is only useful when comparing different applications of the same brightener.

There is a discrepancy between visual impression and a measurable whiteness. The users of brighteners are well accustomed to the really striking effect in the visual range, yet the instrument may only measure slight increases, such as 1 or 2 points.

The discrepancy between objective and subjective evaluation has various causes, mostly to be found in the peculiarities of the human eye. As a measuring instrument it is not particularly reliable, yet it is a very sensitive and adaptable indicator. Its sensitivity to very small differences may cause overestimation of actual quality of brightness and shade. An additional factor is the subjective effect at the moment of contrast and other psychological effects which cannot be measured.

Although it seems so obviously desirable to adhere to strictly objective methods of measurement, in the end it is the visual impression which counts. This is particularly true as far as evaluation of shade is concerned. Requirements in this respect are constantly changing and they vary according to market location, country, etc., quite apart from the personal preferences which are found in individual persons; e.g., in the final analysis your customer's eye is the one thing you have to satisfy.

### THE TECHNIQUE OF OPTICAL BRIGHTENING ON PAPER

Brighteners can be introduced in:

I. Pulp Manufacturing. One of the major selling points of pulp is brightness. It is conceivable that pulp mills could bleach to a higher brightness more cheaply by using additional equipment and chemicals. However, pulp yields, strength, and opacity go down considerably when the pulp is purified beyond a certain brightness.

Brighteners can give the additional few points without the above mentioned drawbacks.

II. Papermaking Equipment. (a) In the beater, (b) by immersion of the paper in the size press, (c) by coating of the paper on the machine, (d) by spraying or waterbox treatment at the calendar.

III. The Converting Operations or Coating Operations. The choice of the right brightener for the above mentioned operations is of uppermost importance as these brands vary radically, both in shade and effectiveness, under existing conditions.

For the sake of brevity of this "paper" we will confine ourselves to the internal application of brighteners in papermaking, i.e., beater use.

### AFFINITY FOR VARIOUS PULPS

Until recently we believed that brighteners have had no affinity for groundwood. Today we know that they are as substantive to groundwood as well as to any other pulp.

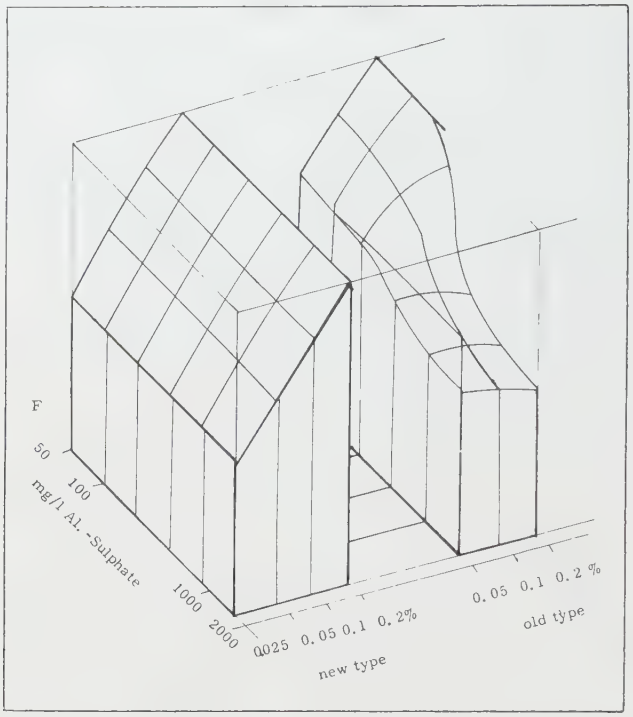



***Fig. 3. Influence of aluminum sulfate when brightening in the beater***

The pulp is optically brightened and the alum added afterwards. The acid stable brand is clearly better.
From now on we shall refer to pH-sensitive brand as "old type"; acid-stable brand as "new type."

Under ideal conditions the exhaustion is between 90 and 100%, whether the pulp is sulfite, kraft, or groundwood, whether it is bleached or unbleached.

The effectiveness, however, i.e., the increase in brightness, varies considerably. There is always a greater gain on thoroughly clean bleached pulps. On groundwood there is almost no increase in brightness. We believe that the lack of efficiency on unbleached pulp and on groundwood is due

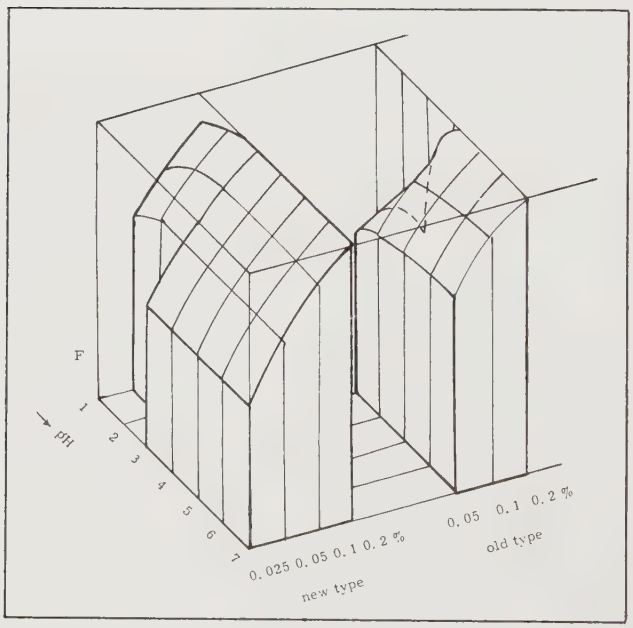



***Fig. 4. Influence of pH of the pulp***

Paper unsized.
Acid-stable brand is scarcely influenced even at pH 2.
pH-sensitive brand begins to lose effectiveness at pH 4 to 5.

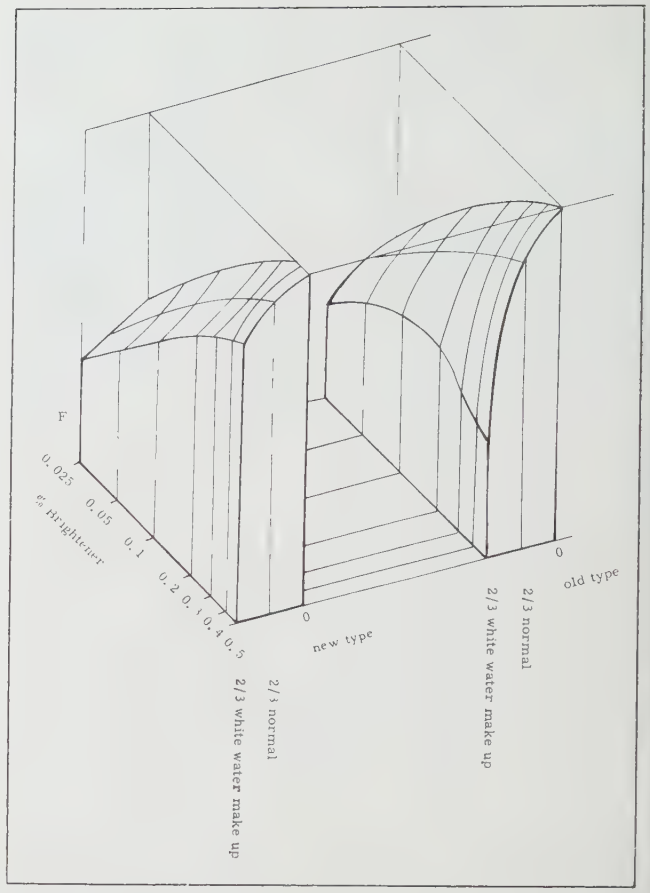



***Fig. 5. Influence of sizing or make up water being used for sizing***

"$^2/_3$ acid sized": Sizing with 2% rosin and 3% alum using whitewater containing 1.2 g. aluminum sulfate per liter.
"$^2/_3$ sized" : Normal sizing as above, but using pure water.
"O" : Unsized.

to the presence of substances related to lignin, which act as ultraviolet absorbers and prevent the brighteners functioning.

Other adverse conditions that influence the maximum efficiency in the beater are as follows: pH, alum, size, fillers, wet-strength resins, dwelltime, temperature, order of addition, and concentration.

### *pH*

The normal brightener works best at a pH between 6 and 8. There is a gradual decrease in brightness as the pH is lowered and its effectiveness is "stopped" when a pH of 4 to 4.5 is reached. From a practical standpoint this is due to two reasons (1) increasing amounts of free acid in the whitewater, and (2) chemical reaction between the aluminum ions and the brightener. These two factors prevent the exhaustion of the compound by lowering the solubility and forming nonfluorescent materials. In fact, these latter materials are yellow in appearance and if they are present in sufficient concentration they will give shades all the way from a greenish white to a yellow.

This explains, partly, why a sized sheet needs approximately four times more brightener than a neutral nonsized sheet, where old type brighteners are used.

Work has been done on this deficiency and now there has appeared on the market a limited number of brands which have greatly improved this problem. A particular characteristic of these new brighteners is their property to remain effective at pH values and aluminum sulfate concentrations where the previous commercial brands are ruled out. To illustrate this phenomenon Figs. 3, 4, and 5 have been prepared.

### *Sizing*

Rosin size is an ultraviolet light absorber and has a nullifying effect on brightness, similar to what we have seen in the case of groundwood. This effect is quite independent of acid or alum stability. Therefore, the choice of a good rosin size

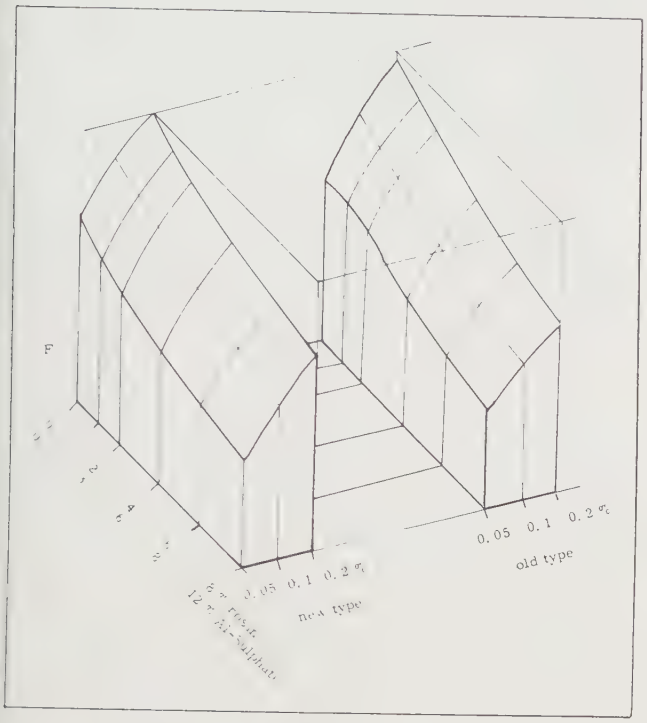



*Fig. 6*

is important. There are a number of synthetic sizes on the market which would bear investigation but, up to now, we have had no opportunity to go into this particular phase.

### *Fillers*

The choice of fillers is of prime importance. Obviously it is desirable to avoid the use of yellowish fillers, especially in the case of clays. Beyond that, the "dulling" effect of fillers appears to be directly connected with their refractive index and their covering properties.

It is our opinion that in the case of titanium dioxide these "phenomena" prevent the incident light rays from activating the fluorescent materials and/or scatter the reflected light. To some extent titanium dioxide is also an ultraviolet light absorber.

The higher the refractive index number the lower the fluorescence effectiveness. The lower the opacity the higher the brightness.

### *Dwelltime and Order of Addition*

Since brighteners need up to 40 min. to obtain maximum exhaustion and, if whitewater is used, it is preferable to bring the pH close to 7 with TSPP or other alkaline media before size and alum are added. If the product tends to granite, add it after the size but before the alum.

It is never advisable to add the old type brightener after size and alum, either in the beater or in the machine chest, because it has the tendency to yellow.

### *Temperature (in the Beater)*

In the case of one or two products, the effect of lower temperatures of the beater water, especially in winter, may adversely affect their exhaustion. But most brands tested in the laboratory in the range from 40 to 110°F. show negligible differences in brightness.

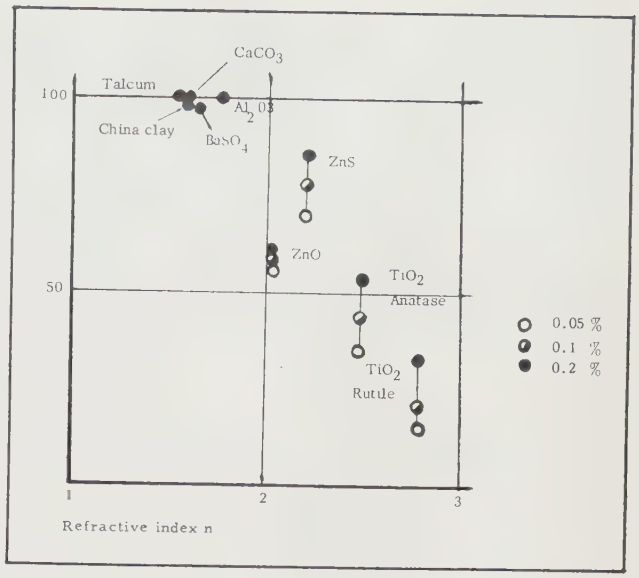



*Fig. 7*

### *Temperature of Drying*

With higher drying temperatures there is a distinct loss of effect with all of the brighteners. The temperature tested was between 212 and 270°F.

### *Wet-Strength Resins*

In the case of wet-strength resins the low pH factor affects the ordinary brands considerably. All brighteners are affected to a marked degree by melamine resins.

Many U. F. resins can be tolerated and do not show the distinct brightness loss as in the case of melamines.

### *Concentration*

The optimum amounts that can be tolerated depend on the particular mill conditions. The maximum amount of, for instance, a single strength product is between 15 to 20 lb. per ton in the case of a sized paper, and double that for a neutral unsized sheet. Beyond this point a definite decrease in efficiency will become noticeable. Generally speaking, mills will work in the range of 10 to 12 lb. per ton. Beyond this point additional amounts do not give correspondingly additional brightness.

To conclude this study: It is obvious that a potential market of this size is a great incentive for us to further improve our brighteners.

We know that our research laboratories have a team working full time on this project.

So far, we have progressed from *powder* to *liquid* to an *acid-stable* product.

As a result of continuing research into brighteners and their application, we hope to work with the paper industry in developing white papers which can be produced "without headaches," whether the brighteners are applied in the beater, on the size press, in coating, by calendering or even on the pulp.

We thank you and all paper men for the cooperation given to us in our efforts. The results, we believe, will be beneficial to us all.

Presented at the meeting of the Northern District of the Empire State Section of TAPPI, held in Watertown, N. Y., March 9, 1960.

The author gratefully acknowledges the contributions received from the Research Department and Application Laboratories of Sandoz, Ltd., Switzerland, and Sandoz, Inc., New York.

## *Gulf Coast*

The fourth meeting of the 1959–60 season of the Gulf Coast Section of TAPPI was held at the Cove Hotel in

Panama City, Fla., March 18, 1960. St. Joe Paper Co. was the host mill for the occasion with Kenneth Bateman serving as local arrangements chairman. Tom S. Coldeway, vice-president, St. Joe Paper Co. welcomed the group to the meeting and invited them to tour the St. Joe mill Saturday morning.

Bruno Leto served as program chairman. Papers were given by D. G. Sutherland and William J. Nolan.

D. G. Sutherland, sales manager, Pandia Div., The Black-Clawson Co., spoke on, "A Study of Hardwood Refining."

Dr. William J. Nolan, professor in charge, Pulp and Paper Laboratory, College of Engineering, University of Florida, spoke on "A Step Toward the Realization of the Pulp Mill of Tomorrow."

N. M. LeMaistre, *Secretary*

## A Step Toward Realization of the Pulp Mill of Tomorrow

*W. J. Nolan*

About two years ago this Gulf States group was exposed to the details of a dream involving the kraft mill of the future. Many of the details of this dream appeared pretty farfetched at the time, as evidenced by the expressions on some of your faces during the presentation. At this time I would like to bring you up to date on what has been accomplished toward making this dream mill a reality.

First, the dream mill was shredding all chips before cooking, at a power consumption of 0.5 hp.-days per ton. At the present time, one Florida mill is shredding about 1600 tons of o.d. chips per day and charging them into batch digesters. Two 600-hp. attrition mills are used for the operation. Tests have shown that, on a continuous operation basis, each machine will shred 2000 tons of o.d. wood per 24 hr. with a power expenditure of 0.2 hp.-days per ton.

I wish it were possible to state that this kraft mill was charging the shredded chips into the dream digester. Unfortunately, the continuous digester described in the dream is not quite ready for production. The mill is charging the shredded chips into the usual batch digesters and is using a cooking cycle corresponding to standard mill procedure for the manufacture of linerboard. However, as a result of shredding, the mill has realized a 14% reduction in active alkali, an increase in pulp yield of 4 to 8%, and has eliminated the need for knotters. The pulp washes on the brown stock washers almost like a screened pulp.

How close are we to an actual installation of the continuous digester predicted for the mill of tomorrow? A pilot plant digester, large enough to produce 3.0 tons per day o.d. kraft pulp of bleachable grade in a cooking time of 30 to 35 min., is now being installed at the University of Florida laboratory. We had hoped to be able to present actual operating data of the pilot plant at this meeting. However, the usual delays in equipment delivery plus necessary design changes have caused postponement of the start-up date. It is expected that the system will be in operation some time in May of this year.

The operating principles of the digester, called the UFAN digester system, are as follows: see *Tappi* 43, No. 1: 128 A (Jan., 1960).

1. Transportation of shredded chips in a large excess of white liquor (4.0% consistency) through a pump to develop a hydrostatic pressure greater than the steam pressure in the digester.

2. Removal of all excess white liquor by pressing, maintaining the hydrostatic pressure on the system, and replacement of this white liquor by recirculated black liquor, already at digester temperature and pressure. Consistency at this point is 9.0%.

3. Provision of a slowly rotating screw in the digester to prevent settling of chips at the low upward velocity used and to insure that each chip moves upward at the same velocity as the liquor with which it entered the digester.

4. Separation of excess liquor by pressing to 25% consistency as the pulp leaves the digester. The press is maintained at full steam pressure to avoid flashing. Part of the excess liquor is recirculated in the digester, the remainder goes to recovery.

5. Dilution of the pressed pulp to 3 to 4% consistency with relatively cool, dilute liquor from the washing system. Since this dilution reduces the temperature of the mixture and steam pressure is lost, a balancing air pressure is provided at the dilution tank to control rate of flow through the system.

6. Removal of the cooled pulp from the dilution tank through a positive displacement pump for transportation to the washing system.

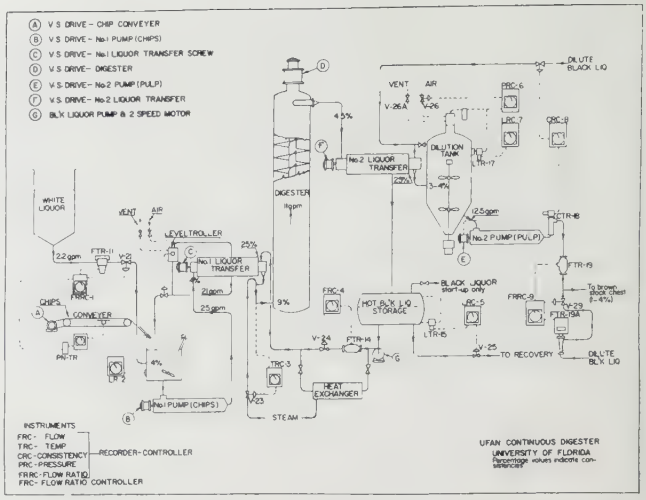



*Fig. 1*

A schematic diagram of the process is shown in Fig. 1 and will be used to explain the operation. Shredded chips are fed to the system (lower left in the diagram) on a belt conveyor equipped with a continuous weighing device. The electrical impulse from the load cell of the weighing device is transmitted to a recorder-controller. The instrument records the weight of wet chips flowing per minute and provides a controlled air pressure (PN-TR) which varies with fluctuations of chip flow. This air pressure controls the flow of white liquor supplied to the chips entering the chip tank. The control is accomplished through the flow transmitter, FTR-11, and is recorded on the flow ratio recorder controller, FRRC-1.

Chips and liquor are kept in uniform suspension at 4% consistency in the chip-liquor tank by a high speed agitator. A progressive cavity pump of the Moyno type takes the suspension from the bottom of the tank, develops about 150 p.s.i. hydraulic pressure on the system (assuming 140 p.s.i. steam pressure in the digester), and transports the suspension to the no. 1 liquor transfer screw. The level in the chip-liquor tank is recorded on the level recorder LR-2.

The no. 1 transfer screw is a specially designed screw press which increases chip consistency from 4.0 to 25%. The pressure casing around the barrel of the screw permits maintainance of full hydraulic pressure on the expressed white liquor. A leveltroller, with balancing air pressure above the liquid level in the float chamber, automatically controls bleed-off of expressed liquor without loss of hydraulic pressure.

Recirculating black liquor is pumped to the discharge of the no. 1 transfer screw by the high head centrifugal pump, G. Sufficient steam is also added with the liquor to insure that steam pressure will exactly balance hydraulic pressure. The high head feature of the pump is used only at startup, in conjunction with the heat exchanger shown in the figure.

W. J. Nolan, Professor-in-Charge, Pulp and Paper Laboratory, Department of Chemical Engineering, Engineering and Industrial Experiment Station, College of Engineering, University of Florida, Gainesville, Fla.

(This heat exchanger is not used in the actual pulping operation.) During actual pulping, the pump is operated at half speed, supplying low head. The black liquor line downstream from the pump is equipped with a magnetic flow meter, FTR-14, and a recorder-controller, FRC-4, which controls the flow of black liquor at a predetermined value through the air-operated valve, V-24.

Sufficient direct steam is supplied to heat the chips and the 3.0 lb. of white liquor plus moisture per pound of chips to cooking temperature. No steam is required for the recirculating black liquor, already at full temperature. A thermometer bulb at the digester entrance actuated the temperature recorder-controller, TRC-3, and the air-operated valve, V-23.

Chips, at 9% consistency, are transported up through the digester by a screw rotating at $^1/_6$ to $^1/_2$ r.p.m., depending on cooking time. The experimental digester is 12 ft. long, from inlet to outlet. If cooking time is 30 min., liquor velocity must be only 0.40 f.p.m. Therefore, helix angle and speed of rotation of the screw are adjusted so that chips will be lifted at this same rate.

Cooked pulp is discharged at the top of the digester as shown. Assuming 50% yield, consistency of discharge will be 4.5%. A bleed-off line at the top of the digester (not shown in the flow sheet) is provided for removal of air, turpentine, and other volatiles. After the pulp leaves the digester its consistency is changed from 4.5 to 25% by pressing in the no. 2 transfer screw. This screw is identical in design to the no. 1 transfer screw already described. The expressed hot liquor flows under full steam pressure to the hot black liquor storage tank.

In the black liquor storage tank, bleed-off of excess black liquor, over that required for digester recirculation, is accomplished automatically by the level transmitter, LTR-15, and level recorder-controller, LCR-5, which actuated the air-operated valve, V-25. This hot liquor would normally be pumped to the evaporators at full steam pressure without the usual flashing to atmospheric pressure and to a temperature of 210°F. or less.

Immediately after being pressed to 25% consistency, the pulp is diluted to 3 to 4% consistency with dilute liquor from the brown stock washers. For every pound of dry pulp, 21 lb. of dilute black liquor at about 170°F. mixes with 3 lb. of cooking liquor at 361°F., resulting in a mixture at about 190°F. A uniform suspension of pulp is provided by the high speed agitator in the dilution tank.

Air pressure is applied at both the discharge of the no. 2 transfer screw and at the dilution tank to replace the steam pressure lost by the temperature drop of the pulp. This air pressure is automatically adjusted to exactly balance the steam pressure in the no. 2 transfer screw. Automatic control is obtained through a signal from a magnetic flow meter (not shown in the flow sheet) placed in the chip-liquor line ahead of the no. 1 transfer screw.

The level of pulp in the dilution tank is held constant by the level transmitter, LTR-17, and the level recorder-controller, LRC-7. Control will be manual in the pilot plant installation, the operator manipulating a vernier rheostat on the d.c. motor drive of the progressive cavity, Moyno pump to maintain constant level.

The pulp discharge pump is unusual in that the suction pressure will be at slightly less than 140 p.s.i. while the discharge pressure will be as low as 30 p.s.i. It is apparent that this pump is being used as a positive action throttling valve rather than as a pump.

The pulp next passes through a consistency transmitter, CRT-18, and a consistency recorder-controller, CRC-8. This consistency controller not only insures a suspension of constant consistency, it also provides automatic metering of the dilution water added at the no. 2 liquor transfer screw.

A magnetic flowmeter, FTR-19, meters the flow of stock at constant consistency. It transmits a signal to the flow ratio recorder-controller, FRRC-9, which records the flow of pulp. The chart on the recorder can be calibrated in gallons per minute or in pounds dry fiber per minute, since consistency is held constant. A flow transmitter, FTR-19A, is provided so that the stock can be diluted to any desired consistency after its flow has been metered.

Through the instrumentation just described, it becomes possible, for the first time, to calculate the yield of pulp at any time. Flow of chips into the system can be read from the recorder which is activated by the weighing device on the chip conveyor. Periodic sampling of chips for moisture content permits the calculation of pounds dry wood into the system per minute. Since pulp flow leaving the system is also recorded, the calculation of yield becomes simple.

It is apparent that synchronism of speeds of the various drives is essential. The speed of the screw inside the digester determines the cooking time. Speeds of the chip conveyor, no. 1 Moyno chip pump, the no. 1 and no. 2 transfer screws, and of the second Moyno pump for pulp discharge must all be synchronized to the speed of the digester screw. Therefore, the motors driving all these units are direct current units, capable of a speed variation of 300%. The control panel for the motors and the power unit is equipped with a single control which varies the armature voltage to all six motors simultaneously. Thus, all motors will change in speed as cooking time is changed by variation in speed of rotation of the digester screw. In addition, a field voltage control is provided for each of the individual motors so that speed of any motor can be adjusted over a 25% range. Tachometers on the control panel indicate output shaft speed of the gear reducer attached to each motor.

An examination of the features designed into the system will indicate that the pulp produced must be of unusually uniform quality. Temperature must be absolutely uniform throughout the digester since steam is added directly into the chip suspension in its pipeline just before entering the digester. No additional steam is added in the digester. Fluidity of the suspension is high with an internal liquor-chip ratio of 9.0:1, insuring that all chips will be in contact with an excess of liquor. The high liquor-wood ratio also permits an initial liquor concentration lower than usually employed. Entering liquor will be at about 35 g. $Na_2O$ per l. while the exit liquor will contain about 18 g. $Na_2O$ per l. Finally, the screw inside the digester insures that each chip remains in contact with its entering liquor, thus avoiding any channeling or short circuiting. Under such circumstances, each chip must be subjected to exactly the same conditions as every other particle and, since chip size is substantially uniform, pulp quality must be extremely uniform.

If the pilot plant capacity works out to the 3.0 ton of pulp per day as planned, a commercial digester to produce 100 tons of pulp per day would be 7.5 ft. diam. and about 43 ft. high. A 200-ton unit would consist of two such digesters in series, using the same transfer screws and pumps as in the 100-ton unit, with the exception that the speed of all units will be doubled.

As soon as the experimental digester is in full operation and sufficient pulping data have been obtained, plans will be made for the University of Florida annual pulping conference, postponed since last December. At this conference the theoretical background of the process will be explained, operational data and a projection of these data to commercial size units will be presented. The pilot plant will be in operation and open for inspection during the conference. The dates for the meeting will be announced through the technical journals.

Now, how close are we to accomplishment of the other features predicted for the mill of tomorrow? Those of you who have seen the March, 1960 edition of *Pulp and Paper* know that the new mill of Waldorf-Hoerner Paper Products Co., at Missoula, Mont., is producing 100 tons per day of bleachable kraft, shipped from the mill in dry bales. The pulp is pressed to 40 to 45% consistency in screw presses,

dried in flash driers, and pressed into 700-lb. bales. The Florida laboratory played no part whatever in this development; in fact, it was unknown to the writer until the writeup of the mill appeared in the journal. It is interesting to learn that others are not only dreaming of new, improved processing but are actively doing something about it.

The Florida laboratory is carrying on a fundamental research program in the fields of brown stock washing with screw presses and continuous, high density bleaching. A small attrition mill-mixer is being built so that high density bleaching studies can be carried out on a bench scale rather than in the 400-lb. batches formerly used with our commercial size equipment. A specially designed screw press has been designed and will be built so that a wide range of performance data can be obtained for kraft, semichemical and sulfite pulps.

We feel that these investigations into continuous processing of pulps are extremely important at this time. The continuous, high speed digester, once installed in the mills, will produce pulps of extreme uniformity. Highly efficient, continuous methods must become available for washing, bleaching, and refining of these high quality pulps. The high degree of automation through instrumentation which always accompanies continuous processing will eliminate most of the guesswork from our pulping operations and permit the production of paper products of a quality and uniformity only dreamed of today.

In other words, the paper industry is now realizing that the pulp mill is a perfect example of chemical engineering processing. As all of the variables in each of the operations become known, the chemical engineer will work in close cooperation with the machine designer, developing equipment which will carry out the operations in accordance with the fundamental laws governing the process. This is a reversal from the older practice of building a piece of equipment from a standpoint of mechanical efficiency with little knowledge or regard for the process variables, then trying to make the process fit the equipment. It is this new trend which may make the dream mill of the future a reality much sooner than many of us think.

Presented at the meeting of the Gulf States Section of TAPPI, held in Panama City, Fla., March 18, 1960.

The cooperation of the machinery manufacturers in supplying the pilot plant with the necessary equipment and instrumentation has been outstanding. Not only have they furnished the project with materials at a fraction of actual cost or at no cost whatever, in many cases they have carried out modifications on standard units to fit the peculiarities of the system. Following is a list of the cooperating groups, without whose help it would have been impossible to carry out the development:

J. Mazer, who supplied the funds for the installation and operation of the digester system;

Goslin-Birmingham Manufacturing Co., who supplied the digester, transfer screws, and all tanks at cost of materials and direct labor;

Robbins and Myers, Inc., who supplied the two Moyno pumps for chips and pulp transportation and a third Moyno pump for high pressure water supply;

Fischer & Porter Co., who furnished all magnetic flow meters, consistency controller, liquor proportioning devices, and level controllers;

Minneapolis-Honeywell Regulator Co., for the chip flow recorder and automatic relief instruments;

Fisher Governor Co., for all air-operated valves and the Leveltroller;

Trans-Weigh Co., for their Belt-Meter used for automatic chip weighing;

The Duriron Co., for their liquor pumps and their plug type, teflon-lined Durco valves;

Mixing Equipment Co., for their Lightnin agitators;

Crane Packing Co., for their specially designed, mechanical seals on all liquor pumps;

Viking Pump Co., for their high pressure pump for bearing and seal lubrication;

Carthage Machine Co., for their 48-in. chipper;

E. D. Jones Corp., for two 28-in. Vertiflex attrition mills;

Link-Belt Co., for conveyors and speed reduction equipment;

United Shoe Machinery Corp., for their chipper knives;

Warren Pumps, Inc., for their Quimby type pump;

Westinghouse Electric Corp., for their direct current motors and gear reducers and for their specially designed power unit and controls.

## *New England*

It was Management Night and 176 TAPPI men stampeded into The Stage Coach Barn, Storrowtown Tavern, West Springfield, Mass., on April 8 to hear Professor Alfred H. Nissan, research professor of Chemical Engineering, Rensselear Polytechnic Institute, discuss "Some Aspects of Hydrogen Bonding."

*A. H. Nissan, Rensselaer Polytechnic Institute*

*R. G. Macdonald, TAPPI*

Hence, the attendance record of 150 set at New England TAPPI's December 11 meeting was shattered under the able chairmanship of John Lewis, Pulp & Paper Research Center.

F. S. Klein, mill manager, Byron Weston Co., and former New England Section chairman, was on hand to discuss the brand new Berkshire District of TAPPI that will hold its first meeting Tuesday evening, May 10 at the Pittsfield Club, Pittsfield, Mass. A. D. Fisher, Jr., Ludlow Paper Inc., will discuss "What is the Real Purpose of Research in the Paper Industry?"

Seated at the head table were: Chairman Lewis; John W. Wendell, Jr., Tileston & Hollingsworth; F. S. Klein, Byron Weston Co.; Thomas Morganstern, Minerals & Chemicals Corp. of America; Alex Hutton, Fitchburg Paper Co.; A. H. Nissan; R. G. Macdonald and James W. Field, TAPPI.

Mr. Macdonald brought greetings from TAPPI headquarters and commended the New England Section for the splendid progress made during the past year.

Dr. Nissan's talk was indeed a masterpiece. He took a most complex and often mysterious subject and explained it so that those with only a basic knowledge of chemistry could readily understand his theories.

The study consists of five steps: (1) a brief review of cohesive forces and of cellulose structure is made, (2) a simplified model is then postulated, (3) a quantitative though approximate law of strength is formulated, (4) the theoretical relationship is checked against observations, (5) the model is refined in the light of observations.

1. Ultimately all cohesive and adhesive forces holding a sheet of paper together must be attributed to attractive energies between atoms. For polymers there are mainly (a) homopolar bonds exceeding 60 Kcal. per g. mole; (b) hydrogen bonds of about 4.5 Kcal. per g. mole; and (c) van der Waals' bonds of about 1 to 2 Kcal. per g. mole. Of these, the hydrogen bonds contribute most of the cohesion between cellulose chain molecules in paper sheets. The structure of cellulose is reviewed and it is concluded that the crystallites are perfect while the amorphous region is liquid like.

2. The model of cellulose sheets is postulated as consisting of nonyielding rodlets in a homogeneous hydrogen-bond controlled amorphous region which takes the strain energy.

3. The theory is built around two concepts: (a) a chain is as strong as its weakest link and (b), statistically, the larger the number of links in a chain the weaker will be its weakest link. Thus, long chains will be relatively weaker but, paradoxically, will require higher rupture energy than short chains.

4. The statistical theory is in reasonable quantitative agreement with observation.

5. From a more detailed study of the comparison with observation it is possible to refine the model and to estimate the van der Waals' as well as the hydrogen-bond contributions to the rupture energy.

A lively round of questions followed the talk.

Chairman Lewis reminded all of the big joint spring meeting

of the Eastern District and New England Section of TAPPI to be held June 3–5, Chatham Bars Inn, Chatham Mass.

JOHN F. O'BRIEN, *Publicity*

## *Pacific (Golden Gate District)*

A plant tour through the Nulaid Farmers Association plant in San Leandro was enjoyed by approximately 40 men, and 78 men attended the dinner meeting at the Cottage Restaurant in Oakland.

The speaker of the evening was D. D. Derricott of the Food Machinery & Chemical Corp., Packing Equipment Division, Riverside, Calif., who gave an excellent presentation on "Problems in the Mechanization of Warehousing and Order Picking in the Paper and Converting Industry."

## *Ohio*

On March 15, 1960, Joseph Parker of Beloit Iron Works addressed 123 Ohio TAPPI members on the subject "Water Flow in Partially Saturated Fiber Beds." The meeting was held at the Manchester Hotel in Middletown, Ohio.

Dr. Parker discussed capillary-held free water flow in partially saturated fibrous media and its practical implications in suction dewatering and hot surface drying of fiber beds. He presented physical and analytical descriptions of the changing geometry of the capillary-held water in fibrous media as they are dewatered. These descriptions were followed by a quantitative concept of liquid permeability in saturated porous media, and the adaptation of this concept to partially saturated systems.

### Water Flow in Partially Saturated Fiber Beds

*Joseph Parker*

LET me first define what I mean by partially saturated fiber beds. A porous fiber bed which is completely filled with water, that is, fully saturated, becomes partially saturated when some of its free water is replaced with air. Thus, partially saturated media contain both free water and air, and the degree of saturation is expressed as the fractional part of the total void volume which is occupied by the free water. For instance, if the degree of saturation is one-third, then one-third of the void space is filled with water, and the other two-thirds is occupied by air.

Partially saturated pulp beds play an important part in the papermaking process. As you all know, paper is formed from a saturated web of pulp fibers. After air penetrates the wet pulp web on the forming wire, the remaining water is removed from a partially saturated system. It follows that the flow of water in partially saturated pulp mats is of fundamental importance in the suction dewatering, pressing, and drying stages on the paper machine.

The rate of water flow in partially saturated media is markedly reduced as the water content decreases. As a result, it becomes increasingly difficult to remove the remaining water. What I wish to present to you tonight, in part, is an analysis of partially saturated fiber beds and the flow of water within them. And, finally, I will discuss the practical implications of this analysis on the suction dewatering and hot surface drying of fibrous beds.

To begin, it is important to know the way in which water is retained in partially saturated media. In beds of pulp, this water is generally classified into three more or less well defined parts, according to how firmly it is held:

The most tightly held water is termed molecularly bound water, and is strongly adsorbed on the surface of the cellulose fibers.

A second less firmly bound part is capillary condensed water, which is retained in the microscopic *intra*fiber pores; that is, pores in the fiber itself.

The third part is free water, which is broadly defined as the water in excess of that required to saturate the fiber. This free water resides in the comparatively large *inter*fiber pores, pores between the fibers. This water, as the name implies, is the most easily removed from the pulp bed, but it is still held by capillary forces.

Because of the somewhat arbitrary definition of free water, there has been generally some reluctance in specifying exact values of the free water content in pulp beds. However, at the symposium on Fundamentals of Fiber Attraction and Bonding last September, Robertson, from the Canadian Institute, proposed a definite critical moisture content as a measure of free water in pulp beds. This critical value of the moisture content was determined from the strength development of the bed during drying, among other methods; and it ranged between 18 to 35% dry fiber. It is the flow of this capillary held free water with which we are concerned tonight.

I have just referred to the *inter*fiber pores in pulp mats and they are of primary significance in the following analysis. It is essential, then, to clarify the meaning of them. These pores refer to the void space in fibrous media; but obviously, discrete uniform capillaries do not exist in real fiber beds. Rather, the void space has a geometry so complex, it defies description. We might properly term it spatial hash. Because we cannot describe this void space simply, it is convenient to represent real porous beds by model networks of cylindrical pores which simulate the behavior of the real systems. As you will see later, the actual shape of the void spaces is an important factor which must be considered in the analysis of partially saturated flow. But for now, it is instructive to think of the pores as cylindrical capillaries, as in the model system. As a further simplification, the following discussion will consider the fibers to have a smooth and well-defined surface. This condition is met in real media with glass fibers; so instead of pulp, I will be talking about glass fiber beds.

In these partially saturated fiber beds, the capillary-held free water always distributes itself in the smallest pores as a consequence of its surface tension (Fig. 1). To illustrate this, the first slide depicts a section of two cylindrical pores partially filled with water and connected by a water filled channel. Because of the surface tension, a curved meniscus forms at the water surfaces and a pressure difference is developed across the interfaces, according to the familiar capillary equation,

$$\Delta P = \frac{2\gamma}{R}$$

$R$ is the principal radius of curvature of the meniscus and $\gamma$ is the surface tension. The pressure on the concave side of the meniscus, which is the air side here, is always greater. So the hydrostatic pressure of the water under the meniscus is less than atmospheric; that is, the water is under suction. This pressure difference across the interface is termed the capillary pressure, and is equivalent to the suction in the water. Since the radius of curvature of the meniscus in the smaller pore A is less than that in B, the capillary pressure, i.e., the suction, in pore A is greater than that in B. Consequently, water will flow from B to A until equilibrium is established; that is, until the menisci curvatures are equal. Thus, so long as the pockets of water in a partially saturated porous bed are connected by liquid channels, the water will migrate to the smallest pores. The smaller the pores, the greater is the capillary pressure, and the more firmly is the water held.

Now, how does this capillary behavior manifest itself in a fiber bed as it is dewatered? In Fig. 2 is depicted schematically a section of an incompressible fiber bed, illustrating the three stages through which the bed passes as its saturation

JOSEPH PARKER, Beloit Iron Works, Beloit, Wis.

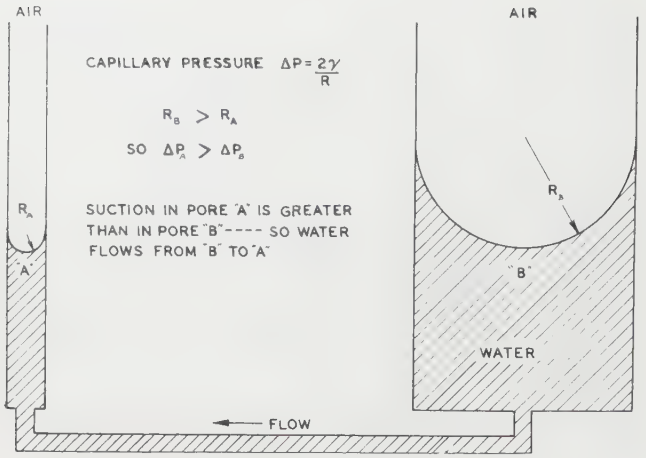



*Fig. 1*

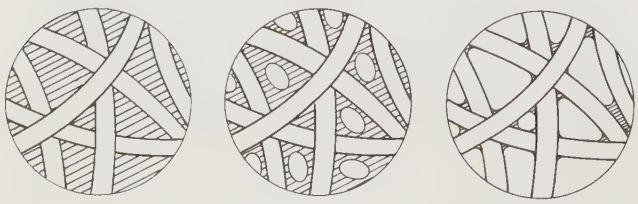
is reduced from a fully saturated condition. We could carry this out experimentally, for example, by air drying the bed. At saturation, all void spaces in the bed are filled with water. The funicular state is produced when air first penetrates the large pores and a continuous network of water channels remains in the smaller pores. If you will visualize this stage three dimensionally, the elliptical areas of air shown are actually cross sections of individual air channels which also form a continuous network enveloped by the water. In this stage, then, the air and water form two intertwining but separate and continuous fluid networks. The physical meaning of a pore here, you see, is not so easily defined. Note, however, that the menisci curvatures in the funicular stage are all the same.

With further dewatering, the continuous water channels are reduced in size as the water retreats into smaller pores and eventually disappear, leaving isolated pockets of water in the crevices at each fiber intersection. This terminal condition is designated pendular and is the minimum saturation which can be achieved by the mechanical removal of water.

From these illustrations, it is visually apparent why the water becomes increasingly difficult to remove, that is, why the resistance to water flow is increased when the saturation is reduced. We can attribute this increase in resistance to three separate effects:

First, as the water retreats into smaller spaces, the total cross-sectional area available to water flow is diminished. This is apparent from the picture of the funicular stage. The water has been purged out of the large pores and is flowing only through the smaller ones. This effect, then, is related to the size of the pores which the water occupies. From the visual irregularity of this water filled space, it does not appear amenable to having a numerical size attached to it, but as you will see later, a meaningful size can be determined for this space by means of the capillary equation.

The second effect of reduced saturation is the increased tortuosity; that is, the water channels become more angular and winding. This is equivalent to increasing the distance



Saturated
All pores filled

Funicular
Continuous network of water channels

Pendular
Isolated pockets of water

*Fig. 2*

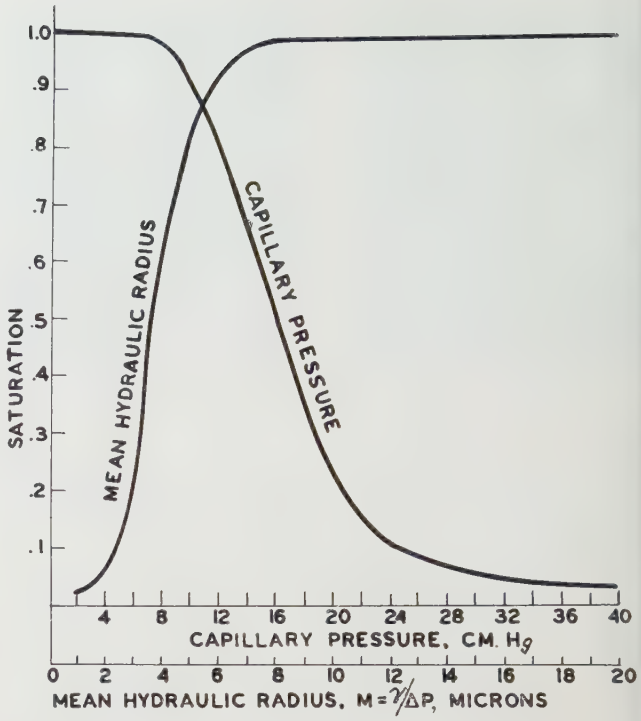



*Fig. 3*

Capillary equation

$$\Delta P = \frac{2\gamma}{R}$$

For uniform cylindrical pores

$$R = 2M$$

$$\frac{\gamma}{\Delta P} = M$$

For real systems

$$\frac{\gamma}{\Delta P} = CM_e$$

$M$ = Mean hydraulic radius of a pore $= \left(\frac{\text{Cross sectional area}}{\text{Wetted perimeter}}\right)$

$M_e$ = effective mean hydraulic radius

$C$ = shape factor

the water must travel to get out. Anyone who has traveled in Boston can certainly appreciate this tortuosity effect.

The third effect is one about which little is known and at best can only be determined empirically. This is the shape of the channels.

The next step now is to define these three effects analytically in order to formulate an expression of the water flow rate in partially saturated systems. I do not propose to get involved in a derivation of the partially saturated flow rate equation now. But as the essential part of such a derivation, I would like to show you how an effective pore size of the channels through which the water flows can be defined. We dismiss the tortuosity and shape factors from our discussion, for they can only be determined empirically, that is, by experiment, in any case.

I mentioned previously that a pore size could be determined for the water filled voids by means of the capillary equation (Fig. 3). You recall that the capillary equation related the capillary pressure, or suction of the water in a pore $\Delta P$ to the meniscus radius of curvature, $R$. For uniform cylindrical pores, this radius of curvature is equal to the radius of the pore if it is circular or to twice the mean hydraulic radius if it is not. The mean hydraulic radius $m$, of course, is the ratio of the cross-sectional area of the pore to its wetted

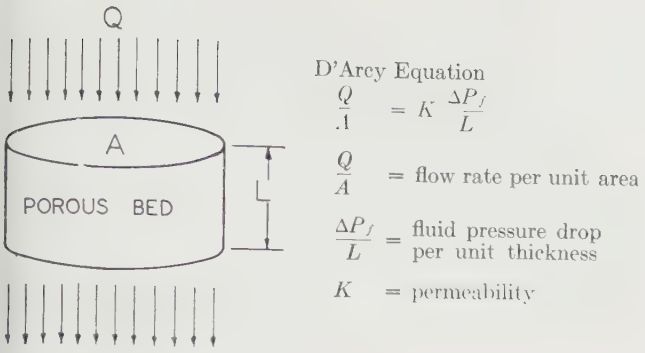



*Fig. 4*

perimeter. Thus, a useful measure of the size of a cylindrical pore is the radius of curvature of the meniscus it contains, which is equal to its mean hydraulic radius. It is determined experimentally as the ratio of the surface tension to the capillary pressure, $\gamma/\Delta P$.

In real fiber beds, the pores are neither uniform nor cylindrical, so their size is not so simply given by the capillary equation. However as a first approximation, it is assumed that the ratio, $\gamma/\Delta P$, of the water in a partially saturated bed, is proportional to an *effective* mean hydraulic radius of the void space which contains the water. The proportionality is completed by introducing a factor, $C$, which is a function of the shape of the void space. Since $C$ is determined by the shape of the void space, it would be expected to have the same value for the same type of media. Thus, while $C$ would be the same for all beds of glass fiber, it would take a different value for a bed of sand.

In this form, then, we can calculate an effective pore size of the space containing the water from the capillary pressure. Extending this concept, we can calculate effective pore size distributions from the experimentally determined capillary pressure curves, that is, curves of capillary pressure versus saturation. Such a capillary pressure curve is shown for a compacted glass fiber bed on Fig. 3. You see from this curve that, as the saturation decreases, the water retreats into smaller pores, and hence, the capillary pressure increases. For each value of the capillary pressure then, we can substitute a value of the mean hydraulic radius, $m$, calculated from the capillary equation. Our capillary pressure curve then becomes a pore size distribution curve, which is shown in the same figure.

So far, I have only talked about the individual factors of importance in partially saturated media. I should like to complete the picture now with an example of their composite effect on the rate of water flow in partially saturated fiber beds (Fig. 4). The usual measure of the capacity of a porous medium to conduct water is its permeability, defined by the D'Arcy equation. This equation states that the flow rate per unit area through a porous bed is proportional to the driving force, or fluid pressure gradient, across the bed. This pressure gradient is the hydrostatic pressure drop in the water necessary to overcome the frictional resistance of the bed. The permeability then is the $K$ term in the equation and is the proportionality factor between the flow rate, $Q/A$, and the pressure gradient, $\Delta P_f/L$. Thus, the permeability is a measure of the ease with which water can be

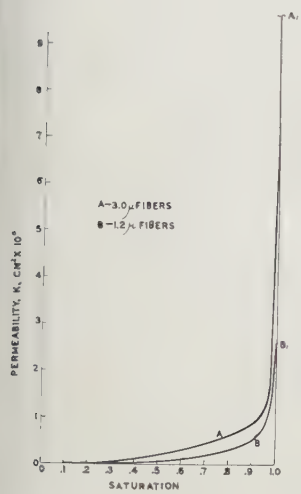



*Fig. 5*

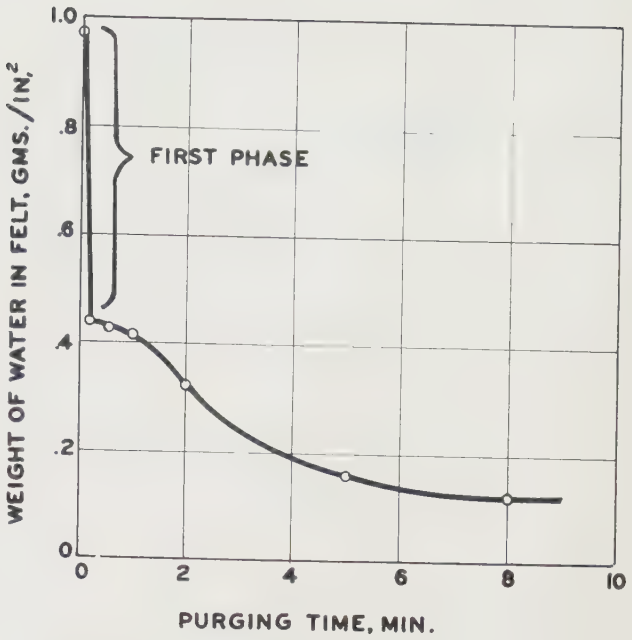



*Fig. 6*

passed through the bed. A familiar frame of reference here might be the freeness of pulp. Generally, the higher the freeness is, the higher is the permeability.

The basic type of flow implied by the D'Arcy equation is that of viscous resistance. Hence this equation applies to both fully saturated and partially saturated media since, basically, the same type of flow occurs in both systems: specifically, the viscous flow of free water in narrow channels. Of course, as we have just discussed, the permeability decreases as the bed is dewatered.

In beds of glass fibers, the permeability falls off very rapidly as the saturation is reduced below complete saturation (Fig. 5). In the figure shown here are experimentally determined curves of permeability versus saturation for two compacted beds of glass fibers. Curve A is for a fiber diameter of 3.0 $\mu$ and curve B is for 1.2 $\mu$ diam. fibers. The permeabilities of the fully saturated beds are indicated by the points, $A_1$ and $B_1$ on the 1.0 saturation axis. As we would expect, the bed of the larger diameter fibers, and, hence, the larger pore sizes has the higher permeability. The extremely sharp drop in permeability as the saturation is reduced initially, is apparently due to the drastic change in configuration of the water channels as the first large pores are opened up. I suggest that this is characteristic of fibrous media, which have unusually high porosities and a sharply angular void shape. Hence, all fiber beds probably have roughly similar permeability curves, but displaced depending on their pore size distributions. You will notice that the permeability reaches zero at a finite value of the saturation. This saturation corresponds to the pendular regime.

Now how does this partially saturated permeability affect the dewatering of pulp webs on the paper machine? To illustrate this, I would like to discuss the application of these permeability concepts to two phases of the papermaking process: the suction dewatering and hot surface drying of fiber beds.

In dewatering pulp webs over fourdrinier suction boxes, the saturation is reduced from complete saturation to about 30% in less than $^1/_2$ sec. Calculated from the permeability curves for glass fiber beds, such a reduction in saturation, controlled by viscous resistance, would require about 6.5 sec. Apparently, then, if you will allow me to approximate pulp beds with glass fiber beds, the rate of dewatering over the suction boxes is not governed by the viscous resistance, but probably by the inertial resistance from accelerating the water in the mat. The degree of dewatering by this method

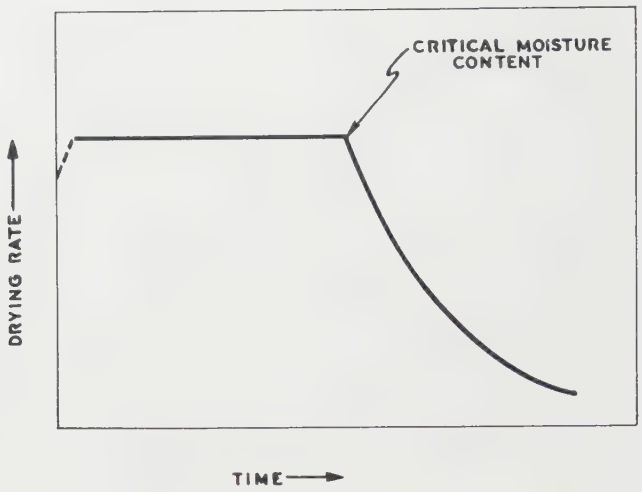



*Fig. 7*

is, therefore, probably limited to the saturation at which the capillary pressure is equal to the inertial pressure developed.

This abnormally high rate of initial water removal by the suction boxes was demonstrated in the laboratory by Riese at Kimberly Clark (Fig. 6). Experimentally, Riese purged water from saturated felts by subjecting them rapidly to controlled air pressures. The curve on Fig. 6 is reproduced from his results and illustrates the two phases of this water removal process. In the first phase, a burst of water particles from the felt occurs which removes up to 90% of the available water in less than one second. I assume that his meaning of available water is the free water content in excess of the pendular saturation. In the second phase, the water is removed much more slowly by the air passing through the felt.

Presumably, it is this initial burst of water which explains the success of dewatering a pulp mat over suction boxes. In support of the suggestion that the amount of water removed by the dynamic suction dewatering is limited by the capillary pressure of the water retained in the bed, Riese demonstrated that the amount of water removed from felts, in this initial burst, increased as the purging pressure increased. Thus, higher inertial pressures are developed by increased purging pressures. As a further study, in light of these conclusions, it would be interesting to determine the effect of pore size distribution on this initial phase of water removal by air purging. We conclude, then, that the viscous flow permeability of fiber beds has little significance in the suction dewatering of pulp mats on the paper machine.

A direct application of these permeability results was made in a recent study of hot surface drying by Wavell Cowan at The Institute of Paper Chemistry. In the process of drying fiber beds, the overall rate of drying is strongly

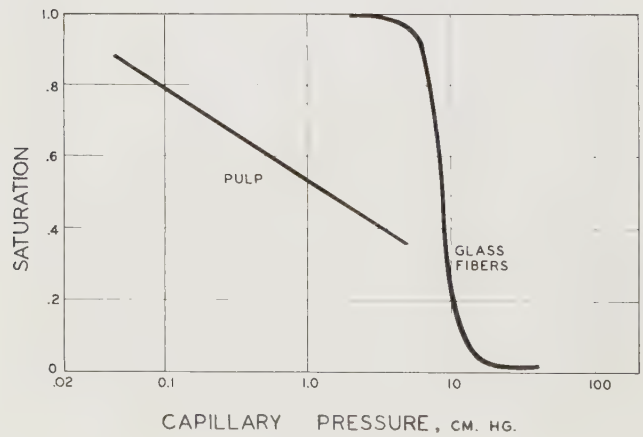



*Fig. 8*

influenced by the rate of liquid water migration within the beds, particularly in the early stages of drying (Fig. 7). This figure shows a characteristic drying rate curve for a fiber bed, in which the rate of drying, that is, the rate of water removal, is plotted against the drying time. In the early stages of drying, at the high moisture contents, the drying rate stays nearly constant and then falls off after some critical moisture content is reached. During the constant rate period of drying, water is being evaporated from the surface of the bed. Water flows to the surface from the interior at a rate to satisfy the evaporation demand. When the saturation of the bed is reduced to such an extent that the rate of water flow to the surface cannot keep up with the surface evaporation rate, the surface of evaporation recedes into the sheet, and the drying rate falls off. Clearly, then the period of constant rate drying is governed by the water permeability of the partially saturated system.

In his study, Cowan derived equations of the transport of water and heat within a fiber bed, which, incidentally was glass fibers, as it was being dried. Experimentally, he measured the distribution of water content and temperature through the bed. In order to complete his material and energy balances, he had to obtain realistic values for both the water permeability and thermal conductivity of his partially saturated bed. Since his glass fiber beds differed only in pore size distribution from those for which the partially saturated permeability was previously determined, Cowan was able to calculate this difference. Hence, he was able to gain an estimate of the permeability of his system directly from those already determined.

I have limited the discussion here, for the most part, to concepts which applied strictly to idealized glass fiber beds. This was deliberate in order to explain the basic mechanism of partially saturated permeability without the complications of secondary effects we would experience with pulp. Admittedly, some of these secondary effects might not be so secondary, but the basic mechanism of free water flow in pulp beds is, I feel, the same. Before I finish, I would like to say just a few words about two of these complicating factors of pulp: the irregular and poorly defined surface of pulp fibers and the compressibility of pulp beds.

Even though the surface of beaten cellulose fibers is extremely complex, it can be characterized fairly precisely when it is covered with an excess of free water. Thus Ingmanson at The Institute of Paper Chemistry has demonstrated that a hydrodynamic specific surface of pulp can be determined accurately and consistently from permeability measurements of fully saturated beds. In partially saturated systems, we should be able to use the same hydrodynamic surface at the high saturations, where the surfaces of the fibers have not been exposed to surface tension effects. As the pulp is dewatered further, however, the configuration of the hydrodynamic surface will probably change drastically as the surface tension causes the fibrillar surfaces to collapse onto the parent fibers. Hence, this changing surface should cause a marked deviation in the empirical shape factor and tortuosity values which were determined for glass fibers.

Compressibility also would necessitate changes in the permeability expression which was derived for the incompressible glass fiber beds. In partially saturated pulp beds, the predominant compacting forces at the high saturations are undoubtedly due to surface tension. You probably know of Lyne and Gallay's work presented at the Symposium on the Fundamentals of the Paper Machine several years ago in which surface tension forces were shown to be the prime contributors to wet web strength and density increase for both glass fibers and pulp. Ingmanson was able to apply classical permeability concepts to compressible saturated pulp beds by accounting for the overall porosity change of the beds due to compaction by the viscous drag forces. In partially saturated pulp beds, in addition to the overall porosity change, we would also have to consider the change

in pore size distribution due to the local compaction of the bed by surface tension forces.

The marked change in pore size distribution of pulp beds as they are dewatered is readily apparent from their capillary pressure curves. In Fig. 8, the capillary pressure curves of a compressible pulp bed and an incompressible bed of glass fibers are compared. The glass fiber curve is confined to a relatively narrow range of capillary pressures, and hence pore sizes. But the pulp curve extends over a wide range, as the local compaction in the bed results in smaller pores and, hence, higher capillary pressures, as the saturation is reduced.

Thus, a study of the partially saturated permeability of pulp beds would be complex, but not unapproachable. The analysis of flow in glass fiber beds provides a working basis for the investigation of these more complex media. However, for any medium, a basic limitation of this type of analysis is that it is based on the voids of the system.

As any doughnut maker will tell you, it would be better to study the solid material instead of the holes.

Presented at the meeting of the Ohio Section of TAPPI, held in Middletown, Ohio, March 15, 1960.

# LETTERS TO THE EDITOR

## *Brightness, Precision and Time*

To the Editor, *Tappi:*

In Scandinavia we are working on new standard pulp and paper testing methods, the SCAN test methods, one of which is for the determination of "brightness of pulp." We do not use the G.E. brightness tester except for calibration purposes; the Zeiss Elrepho reflectometer is the most popular instrument in our countries. However we do not want to dissociate ourselves from the TAPPI Standard brightness level, if possible, which means that we have to use a specific calibration method.

When calibrating one instrument against another the level of the latter must be known with sufficient precision. For that purpose I prepared ten laboratory sheets and measured them in our recently overhauled General Electric instrument as well as the Elrepho. The sample opening is much smaller in the G.E. than in the Elrepho. Elrepho's opening has a diameter of 35 mm. through which a circular surface having a diameter of 30 mm. is measured. Because of this I have made five G.E. measurements on every sample, one in the center and four in a ring closely around it. With the Elrepho every sample was measured only once. The brightness values obtained with the two instruments are given in Table I.

In Table I the means of the values obtained with the two instruments are given as well as their 1% confidence intervals, the latter being a measure of the precision obtained. It is interesting to note that although the number of measurements performed with the G.E. is five times that with the Elrepho, the confidence interval is still about twice as large. This leads me to ask: How many measurements have I to perform with the G.E. before I get a confidence interval of only 0.08 for their mean as well? It can be shown that 150 measurements are needed.

The conclusion is that the larger sample opening and the diffuse illumination of the sample by the integrating sphere reduce the number of brightness determinations needed to $^1/_{15}$th of those required with a G.E. brightness tester. If I add that one performs four determinations with the Elrepho in the same time that is needed for one measurement with the G.E., the above given relation becomes even worse, 1:60. On the other hand, nothing facilitates a lie as much as statistics.

**Table I. Brightness of Pulp Sheets Measured in G.E. Brightness Tester and Elrepho**

| | *G.E. brightness tester — Individual brightness values* | | | | | *Mean* | *Elrepho* |
|---|---|---|---|---|---|---|---|
| A | 93.0 | 93.3 | 93.0 | 93.0 | 92.9 | 93.04 | 93.0 |
| B | 92.4 | 93.4 | 92.7 | 93.3 | 93.3 | 93.02 | 93.05 |
| C | 92.3 | 93.4 | 93.0 | 92.8 | 93.0 | 92.90 | 93.0 |
| D | 93.0 | 92.9 | 93.6 | 93.2 | 92.8 | 93.10 | 92.95 |
| E | 93.0 | 93.4 | 93.5 | 93.2 | 92.5 | 93.12 | 93.0 |
| F | 93.0 | 93.9 | 93.3 | 92.6 | 93.2 | 93.20 | 93.2 |
| G | 93.0 | 92.8 | 92.8 | 92.3 | 92.6 | 92.70 | 93.05 |
| H | 93.2 | 92.9 | 93.2 | 93.2 | 92.8 | 93.06 | 92.9 |
| I | 92.8 | 93.0 | 93.1 | 93.1 | 92.9 | 92.98 | 93.0 |
| J | 93.8 | 92.9 | 93.6 | 94.2 | 93.5 | 93.60 | 93.05 |
| | | | | Mean values: | | 93.07 ± 0.15 | 93.02 ± 0.08 |

Let us therefore reduce the disadvantage of the ratio to 1:30. This means that the precision achieved in one minute with the Elrepho still demands half an hour's job with the G.E.! I hope this will not be considered as any untoward criticism, the G.E. has done a good job, but gradually it has become old enough to retire.

We have these modern, quick, and reliable instruments in common use for measuring brightness. Because of the optical geometry, their level is somewhat different from the TAPPI level. To simplify standardization these levels should be kept equal. This can either be done by an artificial change of level of the instruments having an integrating sphere (specific calibration) or by abandoning the G.E. brightness level.

With the introduction of the G.E. brightness tester, the United States was first in establishing a standardized method for measuring brightness. Now, 25 years later, there are new and modern instruments giving more precise brightness values in a fraction of the time previously required. When will the U. S. A. pulp industry demand a change to a new type of instrument for measuring brightness?

Åke S:son Stenius
*The Central Laboratory of the Swedish Cellulose Industry, Stockholm, Sweden*

To the Editor, *Tappi:*

It is true that variance in reflectance attributable to sample variation is smaller when the test area is larger. The precision of the Zeiss-Elrepho reflectometer is, in this sense, undeniably superior to that of the standard brightness tester. However, we feel that Dr. Stenius has presented a numerical caricature of the actual situation.

In consideration of the basic accuracy (as well as of precision) of the standard brightness tester, it is rarely ever necessary to make more than five determinations on a given sample of pulp or paper. Using any reflection meter, however large the sample aperture, one should make at least two determinations on a given pulp sample; for example, in our use of the Hardy-G.E. recording spectrophotometer (which illuminates an appreciable area of a specimen), we employ a minimum of five test areas for a given sample, and often use ten. Accordingly, we think that a more appropriate basis for comparing operator times is five determinations of standard brightness as compared with two using the Elrepho. Our operators are not selected for the job, nor are they driven under a whip; yet they ordinarily perform 200 determinations of standard brightness per hour. Set against this, Dr. Stenius's time ratio of 30:1 seems unrealistic.

To bring out the nature of Dr. Stenius's caricature, we might exaggerate the picture a little, as follows. Suppose that the instruments and materials were such that the respective "1% confidence intervals" were, respectively, 0.0015 and 0.0008%. Dr. Stenius's reasoning would still

lead us to the concusion that, to attain the better precision, 150 measurements (in comparison with ten) would be required! The point is, that the level of precision should be judged in terms of instrumental accuracy and precision, and the demands of the job to be done. The precision associated with five determinations, as stated before, is generally sufficient.

Study of the individual data presented in Dr. Stenius's Table I is of interest, because it leads to the conclusion that something other than imprecision resulting from smallness of sample aperture is involved. One is often impressed, in calculating a standard deviation or standard error, by the large weight carried by the squaring of certain individual deviations from the mean. Thus, for example, in summing the squares of the deviations of the means from the average of the means, it is noted that the square of the deviation of one mean (that for sample K) accounts for substantially more than half of the sum of the squares. Naturally, then, one's attention is directed to the individual values observed for that samples. If the imprecision originates entirely in the smallness of sample aperture,one would expect those individual values to fluctuate fairly wildly about the mean value of 93.60. Actually, the standard error for this mean is found to be only 0.21. None of the ten means has a standard error greater than 0.21, and the average standard error for a set of five determinations is 0.15. In particular, the greatest spread is found between the means for samples G and K; this is seen to be 0.9%. We generally consider this to be a real difference and in this case the probability of the difference being significant is estimated on the basis of the standard error of the difference, 0.24; thus, 0.9% is about $3.7\sigma$. The chance that the observed spread is not real is roughly one in 5000.

The Zeiss-Elrepho reflectometer is, indeed, a fine instrument. It has been carefully studied on the instrumentation program sponsored by the American Paper and Pulp Association [Dearth, Leonard R., Shillcox, Wayne M., and Van den Akker, J. A. Instrumentation Studies LXXXV. *Tappi* 43, No. 2: 230A–239A (February, 1960)] and was found to be one of the best of a long series of reflection meters.

J. A. Van den Akker,
*The Institute of Paper Chemistry*
*Appleton, Wis.*

# RECENT BOOKS

**Treatise on Analytical Chemistry.** Theory and Practice; Part I, Vol. 1. I. M. Kolthoff, P. J. Elving, and E. B. Sandell, editors. Interscience Publishers, Inc., New York, 1959. $6^1/_2 \times 9^3/_4$, 808 pages. $17.50.

The triumvirate responsible for this treatise need no introduction "Theory and Practice" Part I of Vol. 1, deals with the objectives, functions, and limitations of, and the application of chemical principles to analytical chemistry.

In particular, emphasis has been placed on the fundamental theoretical basis of analysis, while practical discussion is confined to fundamentals and to the interpretation of analytical results. Seventeen authors, each an expert in his own field of analytical chemistry, have contributed to this volume.

**Introduction to Colloid Chemistry.** By Karol J. Mysels, Interscience Publishers Inc., New York, 1959. $6^1/_2 \times 9^1/_4$, 475 pages. $10.

This textbook is based on the author's experience in the teaching of colloid chemistry, at various levels, in the University of Southern California. The fundamentals of colloid chemistry are presented simply, and it is an introductory work which anyone, having a knowledge of the basic principles of chemistry, can follow.

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# SYMPOSIUM ON PULP EVALUATION

## *TAPPI Testing Conference*
## *Portland, Ore., Aug. 19, 1959*

Moderator: Dr. Roy P. Whitney
Panelists: Dr. James d'A. Clark
Dr. Lars Nordman
Dr. W. B. Campbell
Dr. J. A. Van den Akker

**WHITNEY**

Ladies and gentlemen, may we please come to order. It is my privilege to welcome you to this session of the TAPPI Testing Conference, which as you know is to be a symposium on pulp evaluation.

We have a distinguished group of experts here on the platform, and I am proud to be associated with them. I have asked each of these gentlemen to speak informally for a period not to exceed 15 minutes. At the end of each presentation, we shall allow time for perhaps two or three questions or comments from the floor, but rather than permitting rebuttal by the panel members at that time, we shall go through the four presentations to try to set the stage and lay the groundwork for the more extensive discussions to follow. After the individual presentations, we shall give each panel member an opportunity for rebuttal. Following this, we shall open the discussion to anyone from the floor or on the panel.

Pulp evaluation is an inclusive term, with many and varied meanings. Perhaps most frequently it has to do, on the one hand, with the behavior of pulps and furnishes during paper manufacture, and, on the other, with the properties of finished papers and the capacity of given pulps to yield these properties. Sometimes we seem to feel that pulp evaluation is concerned only with answers to the question "what"—"what" is the value of a given property, or "what" is a certain test result? Actually, and particularly within the context of our discussion this afternoon, pulp evaluation is much broader than this. We are going to be much more concerned with other questions—"why" does the property have this value, "why" is it as it is, "how" can we alter it, "how" can we control it, "what" is the ultimate potential of the pulp in this regard? We think that these latter considerations go much beyond the primary question of "what" and that they are much more important to progress, in better utilization of our raw materials and better products from our industry.

Now, there can be numerous approaches to pulp evaluation. At least two seem to stand out as being distinctly different. One is the simulation of refining and papermaking operations in small-scale equipment, and the preparation and testing of handsheets which result from these operations in order to see what the values may be. This is the conventional approach which is used in your mills for pulp evaluation. The session this morning and many of the papers yesterday were concerned with techniques for carrying out small-scale tests, to give values which, in terms of experience, are meaningful.

There is another approach, of course, and that is the identification and measurment of fundamental properties of fibers and fiber systems, and translation from these to predicted sheet properties. This approach seems to offer far greater ultimate possibilities for understanding the things we want to know about pulps and their behavior and their ultimate potentials. So far, it has suffered very badly from our lack of understanding of fundamental properties, from our lack of an ability to identify, measure, and interpret them, and our lack of an ability to translate the results of such fundamental measurements in terms of final sheet properties. So, the second approach has not been used to any great extent in commercial pulp evaluation. This is quite understandable; one does not throw away an existing useful technique because there is conceivably a better approach, until that better approach is worked out.

Today, we are going to be concerned much more with the second technique. What are the factors that underlie pulp evaluation? As we look to the future, how is our understanding increasing? What are the road blocks? What should we learn? What do we need to do? I am sure you know that his has been a very active field for research during the past few years. Much of the research has been directed at an elucidation of fundamental fiber and fiber system properties, and I think considerable progress has been made. However, there is room for argument and for difference of opinion. As new concepts develop, before they are completely understood no one knows just what may be their ultimate significance, and just what should be the ideal course of development. These are the things that we want to talk about.

The field is so broad that we have had to delimit it to some extent; otherwise, we wouldn't know where to start. So, rather arbitrarily we have divided the field into three parts, and the preliminary discussions by our experts will be concerned with these three parts.

The first area is individual fiber properties. Certainly one of the important factors in pulp evaluation is the individual fiber and its properties; the strength of the fiber, the importance of fiber breakage in sheet failure, the stress-strain relationships in individual fibers, and how these factors contribute to ultimate sheet properties. The question of fiber dimensions is important. We had an excellent paper on that subject yesterday. One of the relatively new and interesting techniques is the zero-span tensile test, which we think is approaching the measurement of something closely related to individual fiber strength, and we shall have something to say about this. Dr. Van den Akker is going to talk about this area particularly.

The next area is *inter-* and *intra*fiber bonding (I emphasize the two as being different) and the rupture of both these kinds of bonds during sheet failure. Dr. Nordman and Dr. Campbell will both speak about this area, because of its very great importance. Here we are concerned among other things with hydrogen bonding, with flexibility, conformability, and agglomeration of fibers. It is in this area particularly that the fiber dimensions become important, so we have a cross-correlation between the first two areas. We are concerned about the importance of swelling and the role of swelling in bonding. We are concerned with fiber surface area and its measurement. There are various ways of measuring the surface area of pulp fibers, as you well know. Most of them give different answers, and we are learning why this is and what is the significance of the values which are determined by the different techniques. We are concerned about bonded area in a sheet as contrasted with total fiber area. Dr. Nordman will speak particularly about this. We are concerned not only about the area or the number of bonds, but about the intensity of the bonds, hypothecating an idealized and oversimplified system.

If we could conceive of a means of determining the number of bonds and the intensity of those bonds, we ought to be able to perform some sort of integration to predict sheet strength. This then is the second area that we shall consider.

The third area has to do with changes resulting from beating and refining. We know that fiber and pulp properties change during the operations of papermaking. We know that one can't make very many grades of paper without beating and refining. Sometimes we talk glibly about many things which happen to fibers in beating and refining. Here, we shall try to talk not glibly, but as intelligently as we are able about these things. We are interested in the development of surface during refining, and in the effect of refining on swelling and vice versa. There have been some very fine recent studies, using both optical and electron micrographic techniques on the development of surface, the character of fibers, the changes in fiber characteristics during beating. There have also been interesting developments in the use of hydrodynamic techniques for such studies. These are some of the factors which we are going to talk about, and Dr. Clark will consider this area particularly in his discussion.

I am not going to spend much time introducing these gentlemen, because I think you know them well. Our first speaker is Dr. J. A. Van den Akker who has been head of the Physics Group of The Institute of Paper Chemistry for nearly 25 years. He certainly has contributed very greatly to our understanding of the properties of fibers, and this is the subject of his discussion.

## VAN DEN AKKER

I WOULD like to begin my part of this discussion by saying that it's important for us to recognize that the fiber is a system, it is a structure; we err when we think of the fiber as a little straight filament of a homogeneous, isotropic material. For those interested in reading recent material on the subject, I suggest that (if you have not already done so) you may wish to read the papers given at the Cambridge symposium,[1] and Emerton's recent book,[2] in which are presented very interesting and instructive reproductions of electronmicrographs of beaten wood pulp fibers.

In speaking of fiber dimensions, we naturally talk about the length of the fiber and the cross-sectional dimensions. One doesn't usually do enough about the nature of the cross section and its shape factors. These are very important and should be involved in any serious study of pulp evaluation. As Roy Whitney has indicated, the mechanical properties of the individual fibers are of great importance to the physical properties of paper. We might emphasize that, when we speak of these things, we mean to include the fiber in its wet, water-soaked condition, as well as in its dry condition.

As Dr. Nordman brought out yesterday, fiber length relates importantly to many mechanical properties of the paper sheet; in addition to the properties of the sheet, the fiber length has to do with the nature of the slurry of fibers before the sheet is formed, flocculation phenomena, etc. Fiber length has a strong bearing on the tearing strength, tensile strength, bursting strength, and many other mechanical properties. The cross-sectional dimensions to which reference has already been made relate not only to the strength and stress-strain relationship for the fiber, but especially in the wet condition to the fiber flexibility. The conformability of the fibers in the forming of paper, as you know, is extremely important. The response of the fibers to the Campbell effect (I refer to Dr. Boyd Campbell here) depends importantly on the wet flexibility of the fibers. According to classical viscoelastic theory, the wet flexibility of the fiber will depend on the nature of the material comprising the fiber wall, and the cross-sectional dimensions and shape. If the shape is more ribbonlike or more tubelike, the flexibility tends to be larger or smaller.

Only recently we have learned the real importance of fiber strength.[3] Our first clue to this goes back about 20 years, when we were developing a theory of tearing strength. The qualitative success of this theory has been a strong indication of the importance of fiber strength, at least in the tearing phenomenon. As you are probably familiar with this theory,[4] I shall not go into it beyond recalling that it is based on an analysis of the energy that goes into the tearing of paper, somewhat along the following lines: When paper is torn, the fibers are either ruptured or pulled without rupture from the mesh of fibers. Paradoxically, it takes more energy, in a typical well-bonded sheet, to pull a fiber out of the sheet intact and break all of the bonds that are involved than to break the fiber, when the bonding is good enough for fiber failure to occur. One of many aspects of this theory is the following valuable consideration: if fibers are stronger, the energy required to break them is greater, but more important, there is then a distributional shift from the breaking of fibers to the pulling out of fibers intact. This means that more energy goes into the tearing process, which results, in turn, in enhanced tearing strength. The well-known dependence of tearing strength on interfiber bonding (negative correlation), together with the positive correlation between tearing strength and fiber strength, gave us our first clue to the importance of fiber strength to the mechanical properties of paper.

Of course, we should know a great deal about the stress-strain relationship for individual fibers. There is nothing new about this concept. Lowell Edwards, years ago (roughly 1940, then with the Weyerhaeuser Pulp Division of Weyerhaeuser Timber Co.), designed and constructed a device for recording the load elongation curve of individual water-soaked fibers (actually tested under water). I understand that this unpublished work was very interesting and valuable. Recently, Jayne has published load-elongation characteristics for individual fibers, and these show very interesting effects. At the Institute, we have measured the breaking stress of single fibers[3] and recently have had an opportunity to design and construct an instrument for recording the load-elongation curves for individual fibers. We are hopeful, of course, that this apparatus will be very useful to us in our work on pulp evaluation.

We think that we need to know a great deal more about creep and creep recovery (relaxation phenomena) in individual fibers. There is no doubt in our minds that the creep and creep recovery phenomena of paper are related to these phenomena in the individual fibers. There is a school of thought to the effect that the creep of paper results from the breaking of bonds between fibers. According to our observations, creep must be the result of a combination of both breaking of interfiber bonds and creep within the fibers. All other materials undergo creep, and it is altogether natural to assume that fibers, in particular, do also. We feel that we need to know a great deal more about the more subtle mechanical properties of fibers, such as the response of fibers to shear stress at a fiber-fiber bond. During ordinary tensile stressing of paper, the individual fiber-fiber bond is subjected to shear stress and undergoes shear strain. It is very easy to picture that, if two fibers are bonded together, a load in an individual fiber necessarily means a shear stress on the bond. Now, as a result of the forces arising from many such shear stresses at bonds, the tensile force which can be built up into fibers can be large and, thus, some of the fibers will break. Our recent work has shown that very substantial percentages do, in fact, break when paper fails under tensile loading.

[1] Bolam, F., *Ed.*, "Fundamentals of Papermaking Fibres," Transactions of the Symposium held at Cambridge, Sept., 1957, Kenley, England, Tech. Sect. Brit. Paper and Board Makers' Assoc., Inc., 1958, 487 pp.

[2] Emerton, H. W., "Fundamentals of the Beating Process," Kenley, England, The British Paper and Board Industry Research Association, 1957, 198 pp.

[3] Van den Akker, J. A., Lathrop, A. L., Voelker, M. H., and Dearth, L. R., *Tappi* 41, No. 8: 416–425 (Aug., 1958).

[4] Instrumentation Studies XLVI. Tearing Strength of Paper. *Paper Trade J.* 118, No. 5: 13–19 (Feb. 3, 1944). Theory first given in Report No. 35 to The American Paper and Pulp Association, on "Tearing Strength of Paper" (Jan. 28, 1942).

What is the nature of the failure in the fiber? This depends, probably, on where the failure occurs. It may be an ordinary tensile failure. In a structure as complicated as a fiber, made up of micro and macro fibrils, shear failure, as ordinarily visualized, may not be possible; nevertheless, disruptive shear strains are conceivable; accordingly, it is hoped that technical people will work out means for studying stress-strain relationship for fibers in shear.

The importance of the flexural rigidity of the fibers, wet and dry, has already been indicated, and further work should be done in this area. It is obvious that the *lateral compressibility* of fibers is something on which we are far more ignorant than knowledgeable. It would seem that information on this, particularly important for wet fibers because of its bearing on sheet forming and structure, should be obtained.

I would like to spend a few moments on ultimate properties —ultimate strain and ultimate breaking stress of individual fibers. According to the recent work of Jayne, the ultimate strain of individual fibers is surprisingly low. In paper, the breaking strain is generally less than 3% for the machine direction and 5 or 6% in the cross-machine direction. Considering papers generally, one observes that the ultimate strain of paper is higher than that of the fibers. The very fact that the fibers are randomly, or approximately randomly, arranged in itself will cause the ultimate sheet strain to be higher than that of the fibers. This may seem paradoxical, because we all know that, because of random orientation, the ultimate tensile *stress* that a sheet can withstand must be less than that of the fibers of which it is composed. Strain is a different kind of thing. Just to give you a very old example—creping of paper has a profound effect on the ultimate strain. In any event, the ultimate strain of the individual fibers is of obvious importance to the breaking strain of ordinary papers.

We have already referred to the importance of the breaking stress of individual fibers. A lot more of this kind of measurement remains to be done, and I have indicated that we, for example, are doing this sort of thing; but the length of life argues against working with individual fibers for general strength considerations, and, therefore, we are constantly looking for legitimate means for measuring the ultimate strength of fibers in a quicker way. It is for this reason that, many years ago, Hoffman Jacobson developed the zero-span test, revived by Jim Clark here some years ago when he was doing research at the Institute. During the intervening years many improvements have been made on this interesting device.

I can't cover this subject well in the two minutes remaining to me, so I shall emphasize just two things. First, if one is looking for an indication of legitimacy of the zero-span test he should plot the test result against the clamping load. In principle, the curve should start at zero and, if the clamping pressure is made high enough, the curve should return to zero because the fibers are snipped in two. Now, does the curve display a simple maximum, or does it have a plateau? If it simply rises to a maximum, and then declines, the observation is not very gratifying. It merely means that at least two phenomena are taking place: One is slipping (at low clamping loads), the other is snipping (at high clamping loads), and there is *no legitimate regime of clamping.* If there is a plateau, this is a necessary if not sufficient bit of evidence that the test has real validity. We are glad to say that according to work done a number of years ago by Will Wink (who is attending this meeting) there is, indeed, a plateau. This was very encouraging to us; recently, Will has been going to different jaw widths and examining the effect of different compressive stresses at the clamps for these different widths. In this way he has produced a significant improvement in the method. This is one of those methods in which any increment in the result signifies an improvement.

The second point I wish to make relates to the material in the publication (earlier referred to) on the importance of fiber strength[3]; we presented there a very brief synopsis of the theory that relates the zero-span test with the strength of the individual fibers. The result of this theory is that the breaking load in the zero-span test should be three-eighths of what you would get if you had all the fibers lined up. Now, on measuring the strength of individual fibers from a pulp and taking the zero-span of these fibers in the form of sheets, close conformity with this factor was observed. The improved zero-span device has boosted test values, and this would improve the agreement, if the experimental work were repeated. The combination of the plateau to which I have referred and the rather good agreement between the theoretically predicted and the observed zero-span values leads us to believe that the zero-span test, as it exists today, is a pretty fair measure of individual fiber strength.

WHITNEY. Thank you, Van.

We shall move now to the area of inter- and intrafiber bonding, and our first speaker will be Dr. Lars Nordman. Again, I don't think I need to introduce him. You know he is from the Central Research Laboratory in Helsinki, Finland. You heard him give an excellent paper yesterday. Perhaps you should know that he came over to this country specifically to attend this meeting. He is going to speak now particularly about the use of optical techniques for measuring some of the fundamental properties of fibers.

## NORDMAN

THE strength of paper is traditionally ascribed to the action of a number of basic factors such as fiber length, fiber strength, the flexibility of fibers, the friction between fibers, and the bonding between them. Of these factors, the most important seems to be the bonding, and all the aspects of this feature have attracted considerable interest during the course of the years.

Bonding presupposes a much more intimate contact between fibers than that required to cause frictional forces. The operative word seems to be "contact," and in investigating the problem of bonding the extent of the contacts and their distribution, as well as some value which characterizes the degree of closeness of the contacting fibers, are required.

As a rule, the purpose of any figure denoting strength is to check the efficiency of some step in the process, or of the paper-making procedure as a whole. The choice of pulp quality and the beating of the pulp are of course the most important steps in this connection, and it is evident that these two factors do to a considerable degree exercise their influence on the strength of the paper resulting from the bonding.

The extent of the contacts existing between fibers can be defined as the total area of contact or bonding which exists between a certain quantity of fibers. The distribution of contacts, or in other words the distribution of bonded area elements in the paper should, it is true, be the distribution in space. However, if the distribution in the thickness direction is neglected, the projection of the bonded area elements on to a plane parallel to the plane of the paper can be considered as the distribution pattern. In a way, this is related to the formation of the paper, only in this case the total amount of fibers is not *a priori* the governing factor, but the quantity of fibers which form bonds with their neighbors.

The degree of attraction existing between fibers which are bonded to each other is the third important factor, and can be expressed as the total maximum force which can be brought to act over one unit of area of contact, this again being dependent upon the number of points within the area over which forces can act, and the strength expressed in any convenient unit of these elementary forces. Another convenient way of expressing the degree of attraction, which is more closely related to the concept of the strength of bonds in general, is the energy required to cause a complete separation of two mutually bonded unit areas. In order to assess the bonding strength in accordance with this latter definition, it is thus necessary to measure the amount of energy which will cause a separation of two previously bonded areas.

For the purposes of measurement, the bonded area can be

most conveniently considered as the difference between the total surface area of the pulp available for bonding before the sheet-making, and the area remaining unbonded after the sheet-making. The reason for this apparently devious definition is of course the fact that there is a convenient method, the optical one, for measuring the unbonded or free surface area.

The measurement is based on the fact that optical scattering in turbid media occurs from interfaces between matter having different refractive indices. An air-fiber interface will thus contribute to scattering, whereas two fiber surfaces in sufficiently close proximity to each other will allow light to pass through unscattered. The theory behind the calculation of the specific scattering coefficient was developed by Kubelka and Munk, and has since been the subject of a number of developments which have made it suitable for adaptation for paper. Since the time Parsons found that the specific scattering coefficient of unbonded fiber sheets was proportional to the surface area of the pulp, the scattering coefficient has been widely used as a measurement of the free, unbonded surface area of the fibers in paper.

Even if the scattering coefficient is expressed in units of area per gram of paper, it must be remembered that this is not the geometrically measurable free surface area of the sheet, but that it is merely proportional to it.

The definition of bonded area, which involves both total areas and free areas, brings the question of bonding very close to the two important factors in the papermaking process, mentioned above, namely the pulp quality and the properties achieved by the pulp through the action of the beater. As is well known, one of the main functions of the beater is to increase the total surface area of the fibers, and thus to create possibilities for the formation of bonded areas. For the measurement of total surface area, however, there has not yet been found any unanimously accepted measuring technique. Even when such a technique is finally developed, there remains to be carried out a transformation of the values for the surface area of the pulp and of the unbonded fibers in the paper, in order to make possible the calculation of the bonded area as a difference. All these difficulties made us seek an easier solution, and we thus proceeded along the following lines.

A given beaten pulp sample has a total surface area which is unique for this sample, although for the present we are unable to determine its size. If paper is made from this pulp sample under varying conditions, and if as a result of this we obtain paper samples which vary in free surface area, we know with certainty that the differences in free surface area are equal to the differences in bonded area. The obvious way of changing the free surface area, or in other words the scattering coefficient, is by changing the wet pressing conditions. It is thus possible at each state of beating which is equivalent to a certain surface area of the pulp to determine the change in strength caused by a given change in bonded area. In pursuing this line of thought, we found that the relationship between bonded area and breaking strength was linear. Experiments on the same lines were recently carried out by Ingmanson and Thode, who found that corresponding values of tensile strength and scattering coefficient formed a curve which was common for all sheets of the same pulp, regardless of the beating of the pulp. The curve, extrapolated to zero strength, which is equivalent to no bonding, gives a certain value for the scattering coefficient, which can thus be considered as proportional to the total surface area of the pulp in a dry state. Since the curve was common for all series, regardless of beating, this implies that beating does not affect the total surface area of the dried fibers. Our own results clearly indicated a definite influence exerted by the beating, from which it follows that if an extrapolation to zero strength should be ventured, the resulting scattering coefficient, or unbonded total area, would change slightly, i.e., increase with beating. However, the increase in dried total area would be much smaller than that generally expected to result from beating based upon values obtained for the wet surface area of the pulp. In spite of the small difference in the results obtained, it seems that both investigations indicate that a part of the fiber surface developed during the beating in the sheet-making procedure and the subsequent drying re-forms bondings within the single fibers which do not contribute to the strength of the paper.

When determining the bonding strength in this way, however, one is forced to rely on the forces required to cause rupture of the specimen. It is therefore advisable to consider whether the rupture strength, the most generally employed result of the tensile strength test, is at all suitable as far as bonding strength is concerned.

The tensile test can be described by the load-elongation curve, which can by suitable means be recorded during the test. This curve shows the relationship between the external forces which are brought to act upon the clamps of the instrument, and the resulting relative movements of the clamps. The recorded relative displacement of the clamps is thus a summation of all the movements taking place in the test specimen, while the load acting on the clamps corresponds to the sum of all the reactive forces acting within the strip. The curve is, therefore, smooth and continuous, and gives no due as to the distribution of stresses set up in the strip, nor does it reflect any inhomogeneities in movement within the strip as a function of time and location. The end point of the load elongation curve is of course the point of final rupture of the test specimen. Whereas the load elongation curve reflects the changes in stress and in relative position of the structural elements within the whole strip, the rupture strength is to a considerable extent dependent on the properties of a very narrow zone of the strip, the rupture zone. The work required for prerupture stretching of the specimen is thus less dependent on the chance occurrence of relatively weak regions than is the end point of the load-elongation curve, or in other words the rupture energy. It has been shown by Arlov that the standard deviation of the breaking strength and the standard deviation of the stretch are both significantly higher than the standard deviation of a parameter which characterizes the form of the load elongation curve.

A few other examples of the inadequacy of the rupture strength value for characterizing the average strength of a specimen may be mentioned. Brecht and Wesp have constructed a new folding tester, of which the principle is that a test strip is, under standardized conditions, folded a certain number of times, whereupon the tensile strength of the folded strip is compared with the strength of unfolded strips. What is in fact done is that an attempt is made to localize the rupture in a predetermined zone, which is for this purpose weakened accordingly by means of folding. In this way, the location of the rupture is determined by chance as far as the local strength value is concerned, and not, as in the case of an ordinary tensile test, by the presence of a certain weak region. It is therefore quite possible that the tensile strength, i.e., the average of the strength values of weak spots in a number of test strips, is numerically higher than the average strength of the folded strips. Nevertheless, the folded strips do not always break at the fold. In other words, even if a test strip is considerably weakened by folding, it can still be stronger in the fold than in the areas which determine the tensile strength of the strip.

This effect is the more pronounced the wilder the formation of the paper. For instance, in a set of laboratory sheets, only three strips out of 25 broke at the fold. From the same pulp, handsheets were made so as to avoid cloudiness. In this case, as many as 16 samples out of 25 broke at the fold.

It is generally said that the tensile test selects the weak regions in the strip. This can be shown by mathematical analysis of average strength values and variations obtained for strips of varying dimensions, but it can be observed by

some simple optical tests. The $R_0$ value according to the Kubelka-Munk theory is determined and recorded for a tensile test strip, so that a narrow band across the strip is measured at a time. The resulting curve shows approximately the distribution of free surface area along the strip. A high value is roughly equivalent to high local basis weight. Afterwards, the tensile strength is determined, and the location of the line of rupture is fixed to the $R_0$-diagram, by measurement of the length of the loose ends of the strip. The rupture zone is more often than not located at a minimum value of the curve. The formation of the paper has again a decisive influence, the wild formation more often giving reason for rupture at the weakest zone.

These few examples show that even if rupture strength values are commercially necessary they do not form the best possible basis for an understanding of the bonding strength.

It was therefore thought that the second definition of bonding strength, i.e., the energy required to cause a separation of previously bonded areas, might afford a better basis for determination of the strength of the bonds.

Several tests have shown that structural changes take place within a strip during a tensile test, and that they are at least in part irreversible. Rance found that thickness increases irreversibly, and our finding was that the scattering coefficient increases, indicating the formation of new light-scattering surfaces. By recording the reflectance value of a strip subjected to a load-elongation process it has been possible to obtain reflectance versus elongation curves which are qualitatively strikingly similar to the load-elongation curve. Each phase of the load-elongation curve has its counterpart in the reflectance curve. Since the total surface area is of course constant in tests of this type, and the increase in scattering indicates an increase in free surface area, it must be concluded that the bonded area is decreased in the tensile test. In other words, a gradual breaking of bonds within the strip takes place even at comparatively low stress-values.

Other information of a qualitative nature can be obtained by optical measurements. If the reflectance value is recorded for the whole length of a test strip, as described above, and following this the strip is subjected to a loading-deloading cycle, it can be found by recording the $R_0$ value again, that the increase in scattering, or in other words the breaking of bonds, has not been uniform, but more extensive in some areas than in others. As a rule, a large number of bonds break in spots where the strip shows from the beginning a low reflectance value, which can be interpreted to mean that bond breaking preferably takes place in weak areas.

A qualitative analysis of the data shows that the factor which seems to govern the breaking of bonds, as assessed by the optical test, is the energy consumed by the strip during the loading test. The energy can of course be calculated from the load-elongation curve by measurement of the area falling within a loading-deloading cycle. For the purpose of determining the bonding strength, it is thus necessary that test strips be subjected to loading-deloading cycles. The corresponding values for the increase in the scattering coefficient are recorded and plotted against the energy values. Straight lines are obtained, and the bond strength is calculated from the slope of the line, consequently it is believed that the energy losses not associated with bond breakage will be largely eliminated. The bond strength is thus given in terms of the energy required to decrease the bonded area by one unit of scattering coefficient. Again, it should be emphasized that the area unit is not equivalent to a geometrical area unit.

One of the interesting results of our work was that beating was found to have no influence on the strength of the bonds. However, different qualities of pulp had an influence on this value. An area of optical contact is of course not the ultimate unit into which the bonded area can be subdivided. Within a unit of optical contact there are a vast number of elementary bonds, and their frequency and strength is believed to depend on the pulp quality, probably on the nature and the amount of hemicelluloses present. The influence of beating is thus limited, in that the mechanical action creates possibilities for the formation of bonded areas, but does not alter the contact-forming capacity of the swollen fiber surface.

Our ideas can be summarized as follows:

The free area can be expressed as the light scattering coefficient of the paper.

The bonded area is the difference between the total area and the free area. Since the total area is hard to estimate, testing conditions should be chosen so that the free surface area changes, but the total area remains constant during the test. In this way, differences in bonded area are equal to differences in the scattering coefficient.

Prerupture energy consumption rather than rupture strength should be chosen as a measure of strength to be related to the changes in bonded area, on the grounds that rupture strength is to a large extent dependent on bond distribution and fiber strength.

Bonding strength can thus be expressed as the energy required to transform a unit of area in optical contact into a light scattering area.

WHITNEY. Thank you, Lars. One or two questions, or do you want to go on?

SAM MCKEE (Weyerhaeuser). I noticed that you talked about the scattering coefficient being proportional to the bonded area, and I think that's true, but you haven't separated the inter- from the intrafiber scattering. I wonder if the interfiber scattering isn't a little more important than the intrafiber scattering.

NORDMAN. I haven't done many tests on this question, but I would believe that the *intra*scattering is much smaller compared with the *inter*scattering. Most of the scattering comes from surfaces of different fibers and less from within the fiber.

MCKEE. Don't you think that there is a little need for caution in interpreting scattering coefficient data in terms of bonding strength when we think of bonding as interfiber bonding rather than as bonds within the fiber?

NORDMAN. I should say that even if there is scattering within the fiber and this value is increased or decreased, this is also an indication of change in bonding.

WHITNEY. We consider the question of bonding so important, as I have said, that our next speaker also will devote his remarks to this area. Our next speaker is Dr. W. Boyd Campbell, who is listed here on the program as a consultant. I think that this is terribly inadequate to describe his activities. We all know that for many, many years he was a tower of strength at the Pulp and Paper Research Institute of Canada, and that his work has had a very profound influence on the development of this industry. Dr. Campbell is going to continue to discuss bonding.

## CAMPBELL

THE fundamental property of any cellulose pulp, whether it be from rag or wood, is its ability to bond with itself to make paper. Apparently this property was recognized about 1900 years ago by Ts'ai Lun, who was the first to use disintegrated fibers to make paper. But it is one thing to recognize that bonding does occur and another thing to understand how it occurs and, with that understanding, to find ways and means of best using that property.

Of late years it has become rather clear that the bonding mechanism in papermaking is that of hydrogen bonds. So it may be well to say something about them. According to the Lewis-Langmuir conception of atoms, these consist of, first, a central core having a positive charge equal to the atomic number, next, a series of shells of two, eight, and larger numbers of negative electrons sufficient to balance the positive center. All the elements, up to and including chlorine, have a tendency to make up a complete outer shell of either two or eight electrons. Since this range covers most of the common elements, attention can be concentrated on this group. If there are only one or two, or occasionally three, in excess of a complete shell, the tendency is to lose the excess and so become positive ions of one, two, or three valencies.

If there is a shortage from the perfect set of eight, the set can be completed in either of two ways. An electron can be picked up from an element having a tendency to lose one. In this case the extra electron confers a negative charge and the neutral atom becomes a negative ion. Thus, chlorine having seven electrons in its outer shell, may pick up the needed extra from hydrogen or from sodium and so we have a balance of positive and negative ions.

The other way the shortage can be made up is by sharing with another atom or group of atoms. Such sharing forms the covalent bond most common in organic compounds. This sharing calls for a pair of electrons to be held in common by the atoms. Thus two chlorine atoms, each with seven of its own, can come together to form a neutral molecule of two atoms, each with four pairs of electrons if one pair is in common. A molecule of water has one oxygen atom with its eight electrons, of which two are provided by two hydrogen atoms. For the most part, the hydrogen cores (positive) are held close to the oxygen negative shell to make a neutral molecule. But occasionally one wanders off on its own as a hydrogen ion, positively charged, and leaving a negatively charged OH ion behind. One water molecule in ten million is so dissociated, and so we arrive at $10^{-7}$ as the concentration of hydrogen ions in neutral water.

Where an OH group is attached to some other group by a pair of shared electrons, a similar sort of dissociation can take place. The frequency of doing so will depend on the rest of the structure. If this is such as to make the OH region rather overbalanced in the positive direction, the hydrogen nucleus is liable to wander off as a positive ion and leave the rest as a negative one. This happens with the organic acids, or the oxyacids generally, such as sulfuric.

But even when there is no great tendency for the hydrogen nucleus to drift off by itself, it is still a positive charge, outside any shell of negative electrons, and as such it tends to be attracted toward any pair of unshared electrons nearby. Oxygen, in compounds, has two pairs of electrons shared with other atoms and two pairs not so shared. Consequently there is a tendency for hydrogen of OH groups to be attracted to one of these unshared pairs of an oxygen if it comes close enough. Since it is already held to an oxygen of one molecule and is now in the field of attraction of an oxygen of a second, it forms a bond holding the two together. The strength of such hydrogen bonds varies somewhat depending on the electronic structure of the parent compounds but, in general, it is of the same order as the energy of crystallization. But it does not require any special orientation of the parent molecules.

Hydrogen bonding is much more general than is ordinarily thought. Water, for instance, is a fine example. Ordinarily we think of it as $H_2O$, which it is in the vapor state. But in the liquid state it is $(H_2O)n$, where $n$ has an average value of about three. This is only an average value which depends on temperature, since groups are continually breaking down and reforming.

When cellulose has access to water, the OH groups of the cellulose become hydrogen bonded to $H_2O$ on all available surfaces. This does not by any means indicate that all OH groups of the cellulose have water attached. A great many, in fact about 80% or so, are buried in the interior of cellulose crystals are not accessible to water. These interior OH groups form hydrogen bonds between the parallel cellulose molecules and so hold the crystal together. Once formed, such a crystal is hard to disrupt since many hydrogen bonds would have to be broken simultaneously. It is well that this is so, since if cellulose to cellulose hydrogen bonds could be easily replaced by cellulose to water bonds our cellulose would be water soluble.

In the making of paper we exchange hydrogen bonds in the opposite direction—we trade cellulose-to-water bonds for cellulose-to-cellulose bonds and so tie our fibers into the structure which is paper.

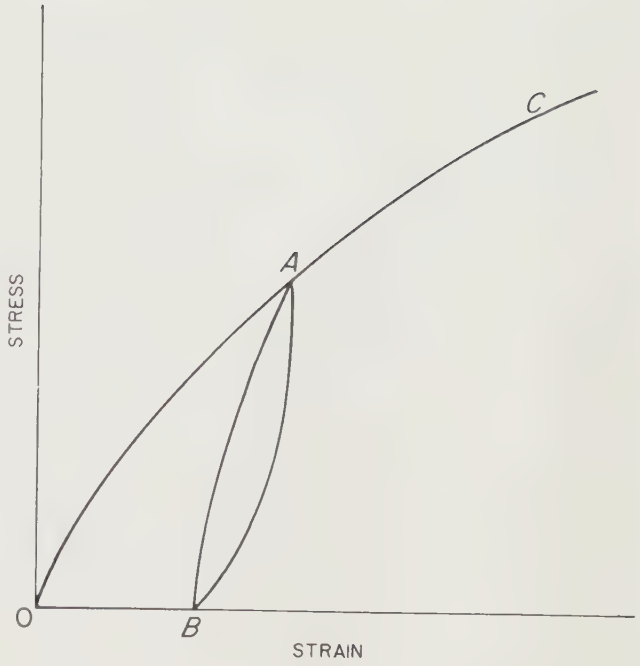


*Fig. 1*

Investigations as to the degree and manner of such bonding in paper are difficult but two outstanding pieces of work in this field have appeared recently. One is Dr. Ingmanson and Dr. Thode of The Institute of Paper Chemistry and the other by Dr. Nordman of Finland. Both of these have made use of the increase of light scattered by the extra surfaces produced when bonds are broken. But there is considerable difference in the manner of their approach.

Dr. Ingmanson measured the extent of bonded surface by measuring the decrease in scattered light in a series of papers made from one pulp, where different degrees of bonding were produced by beating and by wet pressure. Using this measure of bonded surface, he found that equal degrees of bonding resulted in equal degrees of tensile strength, regardless of whether the increase was due to beating or to wet pressure or both.

Dr. Nordman took a different approach. He subjected papers of various degrees of bonding to tensile stress short of the breaking point and measured the increase of light scattering produced by different amounts of energy used to produce the scattering. When paper is subjected to tensile stress, a part of the energy used in producing the strain, or stretch, is elastic and another part is used up in breaking bonds. Referring to Fig. 1, where stress is shown as ordinate and strain, or stretch as abscissa, the curve $OAC$ is the kind of curve obtained in a tensile test. If the curve is carried to $C$, the paper breaks. But if the stress is relieved at some earlier point, $A$, a part of the stretch is regained as the curve follows the path, $AB$. The area $OABO$ is a measure of the energy used in breaking bonds. Matching such energy against the bonds broken (as measured by the increase in scattered light), Dr. Nordman found that, for any one pulp, the energy absorbed was directly proportional to the area of broken bonds. Once again it was found that it did not matter whether the bonds were due to beating or to wet pressure.

But when we compare the two methods, there appears to be a paradox. If, after stopping the loading at the point $A$ and bringing to zero load at $B$, the load is again increased, the curve goes right back to $A$ and from there proceeds to the breaking point at $C$ as if it had not been interrupted. There are some minor departures from this, such as the curve having a slight hump above $A$ on the return. But such slight departures seem to be of little consequence.

But suppose some of Dr. Ingmanson's samples had been

stressed to a point corresponding to $A$ before he tested them. They would have shown, before breaking, a lesser degree of bonding than samples which had not been so stressed. Yet they would show the same breaking load. Apparently the bonded area is not the only factor in ultimate strength.

It is obvious from this that there are many bonds which, though broken in a tensile test, do not contribute to the final force needed to break the sheet.

From Dr. Norman's work, it would appear that, at least for one pulp, the energy required to break the bonds in a unit of bonded surface is constant. But this has little to do with the force required to do the breaking. Force is a measure of the number of bonds broken simultaneously.

Some experiments quoted by F. P. Bowden, *Endeavour* (Jan., 1959), illustrate this very well. With a little care, mica can be split into sheets which are extremely flat. The energy used in splitting can be readily measured. His experiments showed it to be 300 ergs per sq. cm. If the split layers are allowed to come together again soon enough to avoid contamination by air and its impurities, the splitting can be repeated with comparatively little less energy than that used originally. He found second splitting required about 230 ergs per sq. cm. In such splitting, only the bonds along the line of cleavage are being broken at any one instant, so the force needed is small. But when tension is used to separate the bonded layers in such a way as to produce a shear, the force is quite great. He found 1000 kg. per cm. shear. Moreover the layers did not part cleanly. Bits were torn out of one layer and clung to the other. It is this latter kind of shear action we must think of when considering the tensile force needed to break paper.

In the stressing before the final break there must be a great deal of distortion and breaking of bonds while some surviving chains of bonded surfaces get adjusted to carry the load. Another illustration can be given of how such adjustment may be taking place. Suppose four of five strips are put in the tensile tester at once, but that they are slack to different degrees. On applying the load, the one with the least slack will break before the others carry any load. After this break, the next least slack will take up the load until it breaks. And so the load will be transferred from strip to strip until only the most slack one remains for the final break.

Two other workers, Dr. Steenberg in Sweden and Dr. Rance in Britain, have shown some experiments which seem to have a bearing on the matter. Each of them has found that a paper broke at the same degree of stretch, regardless of the rate of loading. Dr. Rance worked with high grade papers such as rag, while Dr. Steenberg worked with wood pulp papers. Between them they covered a range of loading rates of about a thousand million to one. The breaking loads, of course, varied a great deal, about 30 to 1.

This finding of Rance and of Steenberg seems to point to many of our ideas of paper strength being somewhat in error. In most of our thinking, paper has been regarded as a fairly homogeneous material like the metals. But actually it is a structure—as much a structure as a bridge or a car or a piece of textile material. From a fundamental point of view, instead of jumping to the measure of how much load it will take in a standard test, we should be thinking of what happens when the structure is deformed in various ways. What elements of the structure are deformed in the tensile test and how much bond breaking is due to such deformation? It seems obvious that considerable deformation and bond breaking must take place before the load is carried on a series or chain of bonded fibers which transmit a maximum stress in the direction in which it is applied.

We have been rather naïve in looking on tensile stress as tensile and nothing more, forgetting that such stress can be resolved into shear stresses at angles to the tensile load. It is rather interesting to observe what happens in an experiment such as the following. Put in the tensile tester a normal test piece, preferably one cut so the loading is cross-machine direction. Clamp the loading arm at zero position. Then stretch the sample slowly by moving the lower jaw as in the ordinary test. When the paper fails in this way, it does not come apart completely. Fibers extend from one portion to the other. Often one part will show an offset of one or two mm. from its mate. This experiment is suggested, not as proving anything definite beyond the importance of thinking of paper as a structure, but in hopes that it may inspire other experiments not laid down in standard testing methods. From the fundamental point of view of finding out how paper gets the properties it has, we must do something more than look for mathematical formulas or the analogies of springs and dashpots so much favored by rheologists. Rheology is the science of things which flow, and paper does not flow.

Purposely, only slight suggestion has been made as to the structures which might lead to the phenomena shown in Fig. 1. The imagination of most readers is quite well able to dream up many such structures. The real trick is to dream up structures which can be shown actually to exist in paper. It is a field which is as yet quite unexplored.

Quite apart from the fundamental idea of searching for the relations between paper structure and its relation to stress and strain, there is room for considerable argument in favor of paying more attention to stretch in paper testing. For many uses, the breaking stress of paper is of little account but the available stretch is highly important. For instance, newsprint going through a printing press never avoids breaking because of its tensile strength. If it can stretch enough to withstand the variation in the draw of the press, it survives; if not, it breaks. Otherwise it would have to have strength enough to stop the machine.

Again it is sometimes said that if the paper is strong enough to stand the operations of calendering and winding, it will be strong enough to stand the press. But stretching imposed by the winding process is largely lost as regards later use—it corresponds to loading short of the breaking point and then relieving to point $B$ in Fig. 1. The tensile strength is not changed but the available stretch is much diminished.

The Mullen burst test is often frowned upon by purists in the testing world because it is not very definite in what it measures. Actually, if allowance is made for bubble height, it measures tensile in the direction of least stretch. With no such allowance, which is the usual case, its report is a measure of tensile strength, biassed in favor of the sheet with most stretch. Perhaps that is one reason for its popularity among paper users.

WHITNEY. Thank you, Dr. Campbell. Dr. J. d'A. Clark is our last speaker. Dr. Clark is also listed here as a consulting engineer, but that doesn't do justice to his activities. He has been extremely active in TAPPI affairs and affairs of the industry for many years, and has contributed very greatly to our understanding of papermaking. Dr. Clark is going to talk about changes which take place in beating and refining.

## CLARK

THANK you, Mr. Chairman and gentlemen. This afternoon I would like to discuss, as well as I can, my idea of what happens in beating with a view of shedding some light on the properties of pulps.

When fibers are in water and are smashed between two moving bars, there is only a limited number of things that can happen. You can cut the fibers, you can bruise the fibers, you can split the fibers, and you might perhaps curl the fibers. Now cutting is simple—we understand that— and when I talk about fiber length, I am not talking about it as perhaps Dr. Nordman was yesterday. I am talking about the weighted average fiber length by true weight. I think that is a fundamental property of pulp. We pass on to bruising. We don't have any good ways of measuring bruising, which really is internal splitting. Bruising is the thing that causes the softening of the fiber, and the best way of measuring it that we have today, I think, is measuring the specific volume or the

density of the test sheets made in their standard manner. The more bruised the fibers are, the denser the test sheet. The closer the elements are together, the higher the tensile, the lower the tear.

In the case of splitting, I am talking about external splitting or fibrillation. And, I'm talking about the fibrillation you can see in the microscope, which doesn't come until quite late in the beating, as a rule, and submicroscopic fibrillation; you have to use an electron microscope or else the silvering technique to see that very, very fine fuzz that forms as crystallites sticking out. Finally I believe (by analogy as to the way the fibers are put together) that, in addition, you have a molecular fibrillation. I think that Dr. Campbell first drew my attention to it, in talking about two-dimensional partial solubility, sort of a two-dimensional colloidal system on the surfaces of the fiber where the sugar cellulose elements are almost, but not quite dissolved—they are hung there. So when the fibers come together in a sheet of paper and the water goes away, by the forces that he has talked about, the whole structure is locked together.

I'll leave curling for the moment. The fibers are curled only in a special machine, and when they are the density goes up, the tensile goes down, the tear goes up. That is quite simple, and we won't worry about it for the moment.

Let's come back to this question about the cutting, the bruising, and the splitting of the fibers. When you open up a new surface on a cellulose fiber, it immediately becomes hydrated with a film of water. Again, as Campbell has shown, the newly opened surface of the cellulose is so avid for water that it will take it away from phosphorous pentoxide. There's your hydration. We don't have to go any further than that. Those are simple concepts. Now, unfortunately, in late years, this whole business has been snarled up quite considerably by two schools of thought. One, as the chairman has mentioned, I want to call the boiled macaroni theory. That is the one, you know, that attributes all of these properties of beating and what have you to swelling, softening, and increased flexibility. That is the one school of thought. Another school of thought I am going to call the fuzzy fibrillar theory, which, indeed, was started by James Strachan, specifically around 1926. He was an excellent microscopist, and he could see these minute fibrillae that the ordinary person couldn't see in the microscope. People looking at a partially beaten fiber couldn't see any fibrillae and said that there were none there—it must be swelling, and what have you. But actually he could see them, and I know that he could because he was a good microscopist, and since that time electron microscope work has shown that that is the fact. Emerton, you know, is the high priest of this boiled macaroni theory. I think in his recent book he mentions fibrils about two or three times and that's all; whereas I can't help but feel that as long as we are sticking to this boiled macaroni theory, we are not going to get very far forward on our beating or our whole concept of the structural sheet. I will tell you why.

I call it the fuzzy fibrillar theory, not only because there is fuzz present, but because, I'll admit, the subject is quite fuzzy. Now here are some of the facts that I will tell you about.

First of all, moist pulp which has been cooked but never dried, is almost fully swollen—it is not going to swell any more if you beat it. You are only going to knock it apart. It's fully swollen to start with, so I don't see how this business about swelling the fiber during beating means very much, particularly referring to a moist fiber.

Second, the next thing that is against this business of flexibility is the very rapid increase in strength in the initial stages of beating—the strength goes way up, and I don't think that there is really much opportunity in stirring pulp, or gently beating it, to increase either flexibility or swelling. I don't think this swelling happens at all in the case of moist pulp, and the increase in strength is too rapid, in my opinion, to say that it is caused by increased flexibility. I just don't see it.

Third, in work I have done the past few years on dry felting, I have had quite a lot to do with viscose fibers. Prior to that, we did quite a lot of work on using cut viscose for making test sheets. If you make a test sheet with viscose—and you can imagine a viscose with a very high hemicellulosic content and all the xylans and pentosans, and the other funny things that are supposed to increase the swelling and the flexibility of the fibers—you have absolutely no strength. Why? Because under the electron microscope viscose fibers do not fibrillate in the same way natural fibers do. I think this is a very strong piece of evidence that the microfibrils—molecular fibrils—are very, very necessary.

Fourth, if you want to make a sheet out of viscose fibers, you don't put a little bit of stickum in there. Now, mark you, they are soft—they will swell in water. You've got to add up to 15%, at least, of a good gum adhesive to get any strength at all; even then the strength is very poor compared with ordinary papermaking bonds, which, as I say, must be caused by these fibrils.

Fifth, if you add, for example, 0.5% of starch to a groundwood, or to an unbeaten pulp, you will scarcely affect the strength. On the other hand, if you add 0.5% of starch or gum to a beaten pulp, you will get a very appreciable increase in strength, 10 to 15% or more. Why? Because the gum isn't much good unless the fibrils are present. The same as it is not much good when you are using viscose fibers. And when you have the fibrils there, the little bit of gum makes a great deal of difference.

Sixth, if you take a fully acetylated pulp so that the pulp is no longer hydrophilic, you can no longer swell it, make it soft, and do all these things it's supposed to do. When you make up your beaten acetylated pulp into a sheet, you get a surprisingly strong sheet, many times stronger than you can with viscose. Why? Because it is fibrillated.

Seventh, Mosser & Engle showed 25 years ago that if you took a high-alpha pulp and hydrolyzed it slightly with acid, you got a faster beating pulp and a pulp just as strong or a little stronger. Now, on the basis of this boiled macaroni theory, you would think if you put acid on it, it wouldn't swell so much. No acid makes pulps swell—you have to use an alkali. Why did that acid make the pulp beat faster? Because the acid hydrolyzed the long cellulosic chains and made shorter chains, which enabled a more intense molecular fuzz to occur on the surfaces, and, consequently, you got better bonding and quicker beating. I don't know how else to explain that.

Eight, if you take a piece of dry paper and compress it, you don't increase the transparency appreciably until you compress it very, very much. Now, if the fibers were put together as they are in macaroni, and you squashed the dried macaroni pat together, presumably you would get much more surface and contact. And you would increase the transparency, but in paper you don't until you go to quite a high degree of compression. Here again, I think the explanation is that between your fiber surfaces you have the microfibrils, and when you compress dry paper, you merely compress the fibrils. You don't bring surfaces any closer together and thereby increase the transparency.

Ninth, there is an experiment by Dr. Nordman that gave me another idea in support of the fibrillar theory. If you stretch a sheet of paper, the scattering coefficient goes up. It gets more and more opaque, and Dr. Nordman found that if you stretch it and thereby increase the opacity and then you relax the tension, the scattering coefficient goes up still further—the paper gets more opaque yet, to the extent of about 7%, only relaxing the sheet about a half of 1%. How does that sheet get more opaque when you relax tension on it? I don't think there is any explanation than the fact that the fibrils buckle sidewise and clear themselves away and you get a better surface. I can't see how you can explain that phenomenon other than on the fibrillar theory.

Finally, and this I must admit is somewhat fuzzy and so it

belongs to this fuzzy fibrillar theory, I haven't done this work myself, but I am informed that if you take fibers in water and put in some carborundum powder and then stir the suspension with air or with a high-speed beater, and merely rub the surfaces of those fibers and make the fibers up into a sheet of paper, you get a surprisingly strong sheet. Now there you see with a very dilute suspension of the fibers, you are not going to get much softening, you are not going to get much swelling, other than what takes place in the water.

With all these ten reasons, and I suppose that there are more, I can't help but feel that this fuzzy fibrillar theory should have far more attention paid to it than the boiled macaroni theory that is currently in fashion. Thank you.

WHITNEY. Well, ladies and gentlemen, the battle lines are drawn. I think you will agree that the discussion has provided food for thought. Dr. Clark has been eloquent in his defense of the fuzzy fibrillar theory. Yet much of the recent evidence indicates, as Dr. Nordman pointed out, that surface area which has developed on beating very largely disappears when the sheet is dried, and is not effective in bonding. This, in part, lends evidence to the boiled macaroni theory, which was a new term to me until last night. Taking a middle ground, I think that both swelling and fibrillation are extremely important in bonding.

Now we'll give each panel member a very brief opportunity for further remarks which he may think pertinent, but please, gentlemen, don't make it long because we want to let all participate. Van, do you have anything to say?

VAN DEN AKKER. I hope that I won't seem to be the kind of person who just likes to take a position in between two schools of thought, but I think that we are sometimes too fond of saying that we can account for such and such a phenomenon on this theory or that theory. I hate to use the word boiled macaroni—I wish we hadn't introduced that—but I personally think, and I'm sure I'm not alone in this, that wet fiber flexibility and submicroscopic fuzz on the fibers are both awfully, awfully important. I think it's a mistake to think that it's either this or that.

CLARK. Hold it now, Van. Let me read you something from my notes here. The fuzzy fibrillar theory admits the importance of swelling and flexibility, but insists that microscopic, submicroscopic, and molecular fibrillation play the much greater role.

VAN DEN AKKER. I'm inclined to agree that perhaps swelling *per se* is overdone, because swelling—whether it is measured by the Jayme centrifuge method, by direct observation of the fibers, or by liquid or water permeability, filtration studies, etc.—is a factor which depends upon the insinuation of water between the long chains that comprise the fiber. This breaks the cross-links, and anybody interested in the stiffness of high polymers knows that the degree of cross-linking has an awful lot to do with the stiffness. So, I don't think we have any argument that the stiffness is reduced by swelling in water, or if it is an acetylated pulp, by swelling in acetone.

Jim, I think you neglected to mention that you get stronger paper from acetylated fibers if you make the sheets in acetone. I think probably a very similar thing happens there. The acetone goes into the fiber structure and separates the fibrils in which some of the hydroxyl groups have been replaced by acetyl groups. The swelling is merely a symptom of the breaking of cross-links. Therefore, we tend to measure wet flexibility through swelling. This, of course, in principle is wrong. We should be more directly interested in wet flexibility. I say, then, let's concentrate on wet flexibility as such and let's go as far as we can in studying the development of submicroscopic fibrils that are developed on the surface of the fibers in beating.

WHITNEY. Lars Nordman, do you have comments to make?

NORDMAN. I have one question and one reply. The reply is to Jim, who thought he found support for his fuzzy fibrillar theory in one of my curves. I think that it was a stress-strain curve you refer to. I will try to explain the increase in opacity during relaxation in a slightly different way. This doesn't exclude the possibility of the fibrils disengaging and giving rise to more scattering, but my explanation is that when we are going up along the stress-strain curve and are on top of it, just on the verge of going down again, we have a certain amount of load on the strip. As we know, when a strip is subjected to a load, it flows. We can imagine that if we have this flow at 5 kg., we shall also have it at $4^1/_2$ kg. In other words, even if we decrease the load, we have still flow in the sheet and the flow is causing a breaking of bonds. So, there is, in fact, an additional breaking of bonds taking place, also on the downward branch.

Now, the question. I would like to ask Van about one thing. He puts quite a lot of emphasis on the strength of the fibers, on the breaking of fibers. However, have you ever found evidence that fibers break also before the final rupture of the sheet?

VAN DEN AKKER. Yes, I think so. We made observations under conditions where the failure took place very slowly, and one could observe what was going on as the rupture of the shee occurred. First of all, I should say that you see a zone of ruptur forming before the sheet is actually broken. It is then that her and there fibers can be seen to break. I might say though tha some of the fibers break after the zone has actually started form ing; in other words, the failure has really started.

NORDMAN. Will all of the fiber failure take place in the ruptur zone? Or do you think that the rupture zone may be in th middle of the test strip, and you can have breaking of a singl fiber somewhere in the upper part or lower part?

VAN DEN AKKER. I couldn't answer that, Lars.

WHITNEY. Dr. Campbell.

CAMPBELL. I'm afraid that I am sort of in between on thi macaroni and fibrillar question. Jim says that there is no swell ing in beating. Now, there is a swelling. I'm sure of it. The permeability method measures that. And, more than that, the permeability method shows most of the swelling very early in the beating. Not, as Jim says, only at the tail end, which doesn't take place at all. If you look at the specific volume curve, such as Mason and his boys and Ingmanson, as well, have shown, the bulk of the swelling takes place quite early and then it stops or doesn't swell so rapidly after the first little bit. Now tha swelling is really fibrillation, which is the sort of thing that Jim is strong for, but in the early states most of it is internal fibrillation It's breaking apart the fibril bundles of the fiber. I think it has been shown pretty definitely now that there is an elementary fibril in all of the fibers, and that the things you see, even under the electron microscope, are not those elementary fibrils—they are a little too small, except for very special conditions. What you see under an ordinary microscope, such as Strachan saw, are not elementary fibrils—they are bundles of fibrils.

Our experiments showed, about 30 years ago, that there is very little difference in the amount of water in beaten and unbeaten fibers—there is no difference in the bound water. Now, there is bound water, undoubtedly. There is water hydrogen-bonded to every available surface. What you are doing in beating is brushing out this macaroni. Instead of having the macaroni all bunched up in a plate, you are spreading it a bit. And, it is that spreading that gives you more opportunity to have one fiber contact another fiber, and so give you strength in the paper. Whether a fiber breaks or not depends on how well it is gripped. You have to have the bonding to grip the fibers before you can break them. So, the bonding, I think, is by far the most interesting thing, and to tell the truth, we don't know very much about it. In the course of time I think we will learn something more.

Though the macaroni theory says that the breaking apart in the fibers is pretty important, it means that you are putting water in there so as to separate the fibril bundles or maybe the elementary fibrils themselves. After the water gets to the surface, I do think that you have something like the notion that I suggested years ago—partial solubility, whereby the long molecule of cellulose dissolves, say for a fraction of its length and can recrystallize back again on to its parent fibril, or at times reach across and crystallize against another fibril or another piece of cellulose. The reason why you don't get bonding with such things as viscose fibers is that they are all in a brush heap and there is no uniformity so that you can break out any sort of fibrils, as Jim says. That's all right, but you don't get much contact either with those smooth surfaces of viscose fiber. It's like contact of two metals. When you take polished sheets, say Johansson gages which are about as flat as metals can be made, and put them together, they only make a contact at about one two-thousandths of the nominal surface. If the two polished pieces of metal are nice and dry, and you put them together and try to slide them apart, without any film of oil at all, you will tear the surfaces. Actually when two pieces of metal go together, they weld, but they only weld in very, very tiny areas. That has been well proved, and that is the sort of thing that I think happens with viscose—you only touch here and there. You only touch, maybe, considerably less than you do in the metals, which is about one part in a couple of thousand or so.

CLARK. Well, I disagree with Dr. Campbell. In the first place, I think anyone looking in a microscope must admit, even in a beaten pulp, that the fibers are intact and are not much more swollen than they were to start with. I don't see how they can swell—they are as big as they can be when they are in the tree and fully hydrated, and Dr. Campbell made that point himself ten years ago. Now, they will swell if you bruise them internally, and they expand because they get water between the cut fibers. That is something else again. You no longer have an intact fiber, you have an internally fibrillated fiber, not an intact fiber. So, I maintain that beating does not swell a natural fiber. Second, I disagree that you can't make viscose fibers swell in water. They will swell almost as much as natural fibers will, except that not having a reticulated structure, they are not as easily swollen. They swell and they become soft, and I don't see any analogy between putting two Johansson blocks together and contact between viscose fibers is an artificial sheet of paper. Furthermore, as Dr. Elsemere mentioned to me a few minutes ago, Du Pont and others are now making viscose, and I presume they

are stretching it highly as it is spun, which will fibrillate when beaten, and that kind of viscose sheet will develop strength. That just pins this thing down. Here you have one case of a viscose that won't fibrillate—no strength—and a viscose that will fibrillate—it gives strength—they both swell and they are both cellulose.

Now, this business about the specific volume increasing with beating is a mere mathematical figment. It is the result of a very, very difficult analysis of the complicated Kozeny equation. Stan Mason and others did a lot of work on this. They started out to prove that specific surface correlated with beating—they found it didn't. The thing that did correlate with beating, and freeness incidentally, was the specific volume, which after all is not a true specific volume—it's a mathematical specific volume. And I don't believe it.

Now, to go to Dr. Nordman. He said that the breaking of bonds in the stress-strain experiment was due to the residual stress, which snaps the bonds and makes more area. But he just showed a little while ago that if paper is strained up to a point, then the stress is released, and then applied again, you go on from where you left off. I am distinctly dubious, Lars, that you do much breaking if you are going to release the stress there. Because if you do release it completely, and come up again, you come back to the same curve.

Finally, a remark that Van made about the effect of acetone on acetylated sheets, and that is very true. That goes back to the partial solubility that Dr. Campbell talked about a little while ago. If you have acetylated fibers, they are partially soluble in a mixture of water and acetone, and because of that, without necessarily getting the swelling, you get the bonding effect of these fibrils that are present.

Campbell. Jim, you must remember that there has to be some kind of hydrogen bonding, and you have to have surfaces with water in between to get bonding started.

Clark. I am not suggesting that you don't have water. I'm merely talking about the effect of a little acetone in the water with acetylated fibers. It's very beneficial.

Van den Akker. Jim, what kind of strength do you get if you take the acetylated fibers and try to form a sheet in water without acetone at all?

Clark. With beaten acetylated fibers, you get a sheet that is stronger, by far, than, for example, with viscose which has not been fibrillated. This is because you don't have the partial solubility—that two dimensional colloidal suspension which Campbell has talked about and which I think is a wonderful conception. You don't get that with water—you must have some acetone present to loosen up the acetylated molecules of cellulose so you can get this molecular fuzz, these fibrillae which are necessary. Then you get the bonding mechanism, and it is very likely hydrogen bonding.

Whitney. You say you don't get that until you have something to loosen up the structure—isn't that the equivalent of water loosening up the nonacetylated fiber?

Clark. Well, yes. I think it is. But when you loosen the fibers up, you fibrillate them. At least, that's my definition of fibrillation. You get the molecular fibrillation which is necessary.

Whitney. I wonder if a lot of this isn't a matter of definition. We are all agreed that you do loosen the fiber up so that water is permitted to penetrate it to a greater extent. You call this fibrillation and someone else calls it swelling. I am not suggesting that the two concepts are exactly the same, but I do think we are recognizing the phenomena which take place to be somewhat similar.

The so-called hydrodynamic specific volume, measured either by the permeability technique or the filtration technique, has been pretty well shown to have some physical significance. That is to say it can actually be shown that more water is associated with a given amount of cellulose, and this can be correlated with hydrodynamic specific volume. Certainly these figures, both Mason's in Montreal and ours at the Institute, show that you do get an effect—call it swelling or call it increased association with water, but it happens on beating.

Clark. I don't dispute that at all. What I do dispute is that it really is a true swelling and not a hydrodynamic or mathematical swelling, because you can't see that swelling in a microscope with beaten pulp.

Campbell. Why sure, Ingmanson showed photographs of it.

Clark. He didn't show any photographs of swollen fibers which had been beaten, I am sure of that.

Jack Dunning (Abitibi). This discussion has centered about beating. Now, in many of the mills I have been in within the last six months, there are no beaters as such. There are pulpers and various refining machines, such as Jordans, Mordens, etc. I would like to have a definition of what you gentlemen are talking about when you are talking about beating. Are you talking about the conventional beater, or are you talking about the work done by these other machines?

Clark. We are talking about both, and stirring and any mechanical action on the fiber.

Whitney. I think we would define beating in terms of what happens to the fiber, rather than the type of instrument used, whether it is a beater, a refiner, or a malted milk mixer.

Martin (Australian Paper Manufacturers). I wonder if the members of the panel could give me some help in understanding what happens when we beat eucalypt hardwood kraft fibers? We can develop a very high Mullen in those fibers without there being any visible fibrillation under the microscope.

Campbell. I would say that that points to the macaroni theory. According to the swelling notion, plus a little interpretation on my part, what you do in getting that swelling is not to create new surface, but to spread apart the surfaces that you have. Conceivably in the unbeaten pulp, the fibrils are internal—all packed tight together. Theoretically it takes no great amount of energy to separate them so that they are a bit further apart—there is more water in there. But actually, of course, some energy is used. I have never seen anything about the eucalyptus fiber, but I fancy you would find some swelling; in other words, increase in internal fibrillation that doesn't show up as the fuzz that Jim calls for. If you have that swelling, that pulling apart of the internal fibrils, the whole mass becomes softer, and as soon as you press the fiber down, it is much more liable to make good contact with other fibers, and I think that is the way that beating works.

Van den Akker. I don't suppose that this group needs to be informed that the flexibility and pliability of wet fibers, beaten or unbeaten, is orders of magnitude greater than for the dry fiber. Whether much of this submicroscopic fibrillation is formed or not, therefore, when two fibers are brought together either under pressure from an externally applied load, or by what we call the Campbell effect, the stresses available to bring these pliable, flexible, plastic surfaces together are enormous. Dr. Campbell showed this many, many years ago. Whether the fibrils are still in the surface of the fiber, or whether they are partially disrupted and waving around with the thermal agitation in the water, would seem to me to make very little difference. The effective bonding would go far beyond what you could get with rigid surfaces.

Clark. You know there is a lot of ducking of the facts in the case. Strachan was an excellent microscopist, and he could see more than most people could see. He could see these fine submicroscopic fibrillae with his technique, and I afterwards showed they were there by a slight silvering. At the same time Dr. Sears of the Institute showed they were there with an electron microscope. People said Strachan was seeing things in the microscope when he saw these fibrils, and when he said they immediately occurred when the primary wall was removed. And they do, and that is why you get this increase in strength in beating. Because immediately you start beating, you start ripping off the smooth primary wall. And immediately that wall comes off, the thing fuzzes out, as you see from all those pictures in Emerton's book. And that is the thing which gives you this very rapid increase in strength—not an increase in volume. The fibers don't swell—you can look at them in a microscope and measure their diameters—they don't swell, once they are fully soaked. But as soon as you start beating them and knock the primary wall off, then you get this fibrillation and you start getting your strength. If you don't believe that fibrils are there, go look at them in a microscope, because they are there.

Aldrich (West Virginia Pulp & Paper Co.). I would like to have some opinions in case of ultrasonic refining. Do you get fibrillation there to the same extent that you feel you do in the mechanical brushing of a beater?

Clark. With a slight ultrasonic treatment, of course you don't affect the fiber at all, but if you use a lot of ultrasonic treatment, you break up the whole fiber, and other effects come to play, but you certainly get fibrillation.

Samuel Bach (Crown Zellerbach). Dr. Clark talks about the strength of paper being increased in terms of increasing the bond strength and bonding area, and also Dr. Nordman talks of energy increase in terms of increasing the bonded area. We have an experience where we creped paper, deliberately breaking bonds, and yet we increased the energy of the paper. On processes like Clupak, we crowd the fibers together, I presume increasing the contact area, and yet we decrease the tensile instead of increasing it. Would you mind answering this question?

Nordman. That is a comparatively difficult question to answer, because I don't really know how the structure of a Clupak paper compares with a paper which is formed in the normal way. There has been a mechanical action after the formation of the paper which has brought in new factors, and I don't know how they will tie in with the theories. We know, of course, that the strength, as judged by the breaking load, is decreased by introducing this high stretchability; on the other hand, the energy consumption will probably be greater than for paper made in the normal way. We believe there is a relationship between the increase in scattering and the energy which has been consumed, but I cannot, at this moment, tell whether the same ratio applies to a paper like Clupak.

Campbell. Is that Clupak paper very opaque? I've never seen any of it.

Bach. Well, I presume it is, but my real question was—is the bonding area that Dr. Nordman is talking about and Dr. Clark is talking about the same thing? Or, are you talking more or less about an abstract term?

Clark. When you crepe paper, which I presume happens with Clupak, you increase the internal stretch of the paper, and it is more difficult to break it. You do break some of the bonds; there's no doubt about that. During the war, you know, we packed a great deal of food in very weak paper that had been creped, so when the case dropped, the lining stretched, and in that way we were able to do very well.

Whitney. You probably know this better than I, but I'm quite sure that while Clupak requires a lot more energy to break, it has an actual lower tensile strength at failure. Isn't that right?

Bach. That's right.

Aldrich. The tensile strength of Clupak will decrease about 10 or 15% from the original paper, but will depend primarily on how much compaction has been put into it. What is increased is the stretch and the total energy of rupture. It's different from regular creping in that in regular creping the entire sheet goes into sort of a sine wave fold; in Clupak the individual fibers and groups of fibers within the sheet bend and weave, but the two surfaces of the sheet do not bend in harmony with each other. Thus there is more of a random bending and warping than there is in the case of a regular creping operation. That's what causes the difference in the effective work factor, and the regular creped sheet will effectively require no more work to break than the regular paper.

Whitney. I would like to put in a word for this relative bonded area concept. It's certainly a qualitative concept, but I think it's a very useful one. I think that if you look at small sections of paper or fibers, particularly in a wet beaten state, under a microscope or an electron microscope, you will find your faith in the concept of bonded and unbonded area a little shaken, because it seems to be a pretty heterogeneous system. Nevertheless, there has been a great deal of work by Dr. Nordman and his associates and by some of our people at the Institute on developing techniques for measuring this. In some of the recent work at the Institute, our physical chemists have been quite successful in using gas adsorption as a measure of total area in a sheet, using krypton as the gas, and getting quite excellent precision in these measurements. They have measured the amount of light scattered by sheets of various degrees of bonding and also measured the area, by gas adsorption, and find that these correlate quite well. The only way that you can get the so-called unbonded area is to extrapolate this curve back to some zero point, and this is not a completely satisfactory technique. In earlier work at the Institute, it was found that there was one common curve for a given pulp whether the different degrees of bonding were obtained by beating or by wet pressing. Some of the later work, particularly on more highly purified pulps, has shown that this is not true, and that there are apparent differences in bond intensity, depending upon the amount of beating that takes place, and you do not get a common curve for the various degrees of bonding developed by beating, on the one hand, and wet pressing on the other. This, of course, is no more than logical. You would expect that as you do more damage to the fiber, and as you take off perhaps first the primary wall and then secondary layers, you might get different intensities of bonding.

Clark. You know that work on bonding was really initiated by Doughty many years ago at the Forest Products Laboratory, and he found that if you plotted tensile strength against sheet density, as the density went up with wet pressing, the tensile went up in proportion to the density. Then, if you beat the pulp, you get another parallel curve, and it was unexplained at that time why the curves were different. Just as our chairman has pointed out to you, I believe this difference is due to the fact that in beating you remove the external wall, the primary wall, uncover the walls beneath it and you get the fibrillation, and that's where you get the additional strength.

Stewart Rowe (Procter & Gamble). I'd like to change the subject a little bit if we could. In the sanitary tissue industry, the emphasis is a little different from what we have heard today. There is a good deal more emphasis on softness of the finished sheet; of course, strength is necessary, but we find that by changing pulps, you can get greater softness with the same strength. Also, this picture is complicated by the fact that most of these are creped tissues. Now, we are sort of baffled by the problem of predicting whether a given pulp will give improved softness. Softness includes surface feel, which I guess we'll have to forget today, but flexibility of the sheet is the other factor. I wonder if any of these gentlemen can throw any light on this problem.

Van den Akker. First, I should say that those of us who have worked over the years with the problem of softness of the kind of tissues of which you speak recognize that this is one of the most difficult of all of the problems of paper evaluation. For years and years, people have found—and Dr. Clark here was among the first of them—a relationship between softness and stiffness. But, as you know, this is not the whole story. As you said, there is a question of surface feel, and no doubt other subjective factors should come into consideration. Ordinarily the stiffness of thick paper, the equivalent of several fibers thick, seems to depend less on the stiffness of the individual fibers as such, and more on the nature of the paper as a system—as a structure. The engineer's idea, for example, that stiffness can be related to the modulus of elasticity and the moment of inertia of the cross section, applies, at least approximately, to an uncreped sheet. Now, as you go to a very thin sheet, essentially one fiber thick, or maybe on the average even less than one fiber thick, the picture is different. Here, apparently, the stiffness of the paper depends very much on the stiffness of the individual fibers and the extent to which they are bonded together. So, one of the factors from the standpoint of pulp evaluation, I would think, would be the dry stiffness of the fibers, as against the kind of technical problem we have with ordinary stiffness of thick papers.

Campbell. You changed your pulp, did yout not? Well, Dr. Nordman found that different pulps have different bonding strengths, and that may account for a lot of what you observe in practice. The bonding strength of one pulp doesn't depend upon whether it is beaten or pressed to any great extent, although, as Dr. Whitney has said, they do find a little difference after a while, but there is a considerable difference in different pulps. Dr. Nordman is far more able to comment on that than I am.

Nordman. It is true that we have found differences between different pulps in bonding strength. It is probably so that the hemicellulose content is the decisive factor in determining bonding strength. However, I am not going to say which component of the various hemicelluloses has the largest influence on this property. We have too little experience so far about that.

Clark. I think it has been well established that in making a soft tissue, other things being equal, if the tensile strength of the beaten pulp is down, you are going to make a softer sheet of it. Just what has been said now—the question of bonding. You get fewer bonds and, consequently, you get a softer sheet. I'm inclined to agree with Dr. Van den Akker that the thinner the sheet, the more important the individual fiber stiffness or softness is, and those two factors put together are just about as far as we can go at the present time.

Question from Floor. Are there published techniques for measuring individual fiber flexibility?

Van den Akker. There is at least one, which has been used by Dr. Nethercut, who got a measure of the stiffness of individual fibers by mounting the fibers so that they could vibrate as reeds. This is an old technique when applied to other materials—I'm not sure if anybody else had ever done this before Phil for the stiffness of individual fibers. What Phil did was sonically to stimulate the first mode of oscillation of the fiber, measure the frequency, and knowing the length and mass per unit length of fibers, he could get a measure of the flexural rigidity of the fiber. Phil, probably the best reference is your thesis itself, but it was published in *Tappi* wasn't it?

Nethercut. The only comment I would add is that this work was not based on wood fibers, simply because the fibers were so short that we couldn't anchor them as cantilever beams and get sufficient overhanging length to make them vibrate. As a result, we used ramie fibers which are considerably longer and a viscose filament, and hoped that by bracketing wood fibers in this way in terms of crystallinity, we could deduce what happened to wood fibers. I don't know of anyone who has used this technique, Van, on wood fibers.

J. D. Robertson (Sonoco). I would like to direct this question to Dr. Nordman. Could you discuss for us the mechanism of the loss of tearing strength on the development of mullen strength or tensile during beating?

Nordman. I should say that the loss of tearing strength is dependent on the formation of the bonds. We are going to anchor the fibers more tightly into the structure, and in this way, we are going over to a condition where the tearing strength is mainly dependent on the breaking of the fibers themselves.

Whitney. Dr. Van den Akker is a good one to speak to this because he developed a theory of tearing strength which he spoke of earlier as leading to the later work on fiber breakage.

Van den Akker. The point that I made, when I first spoke, was that the energy required to break a fiber is relatively small. Surprisingly, the energy required to break anything is relatively small. It's when you try to pull something out of a system without breaking it that you expend a lot of energy. When paper is torn, some of the fibers in the zone of tear will break, and some won't break. Those that don't break will require a lot more energy in being pulled out than those that do break. So, as Dr. Nordman said, if you increase the degree of bonding so that more fibers are broken, the tearing strength goes down.

Nordman. I could add that some work was carried out in Finland which involved tearing strength of a very thin fabric. It turned out that the fabric couldn't be torn in an ordinary tearing tester. But as soon as the fabric was impregnated with various glues, the tearing strength could be determined, and at the same

time, the values went down as the amount of glue was increased. So, this would also explain the process of the tearing test.

CLARK. May I emphasize that point because all of us measure the Mullen and the tear and think they are very important. Dr. Van den Akker has given you an explanation just now and I agree thoroughly with it, but I think there is a simpler one. After all, if you have a bulky sheet and your tearing is pulling it apart, the more bulky that sheet is, the bigger the zone over which you apply your force. Although you are measuring energy, you can also think of it as a force. And so, the more compact and dense your sheet is, the more intensely is your tearing force applied at the point of the fibers, and consequently, it is easier to break the sheet. I have found, and Doughty has found, that there is a mathematical relationship—the tear is inversely proportional to the sheet density. Now, as far as burst is concerned, the more compact the sheet, the harder it is to pull the fibers apart, and there again mathematically, both Doughty and I have found that the Mullen is proportional to the sheet density. If you increase the sheet density by wet pressing or beating, or any other way by, say, 10%, your burst will go up by 10%, your tear will go down by 10%. We want to bear those relationships in mind because this puzzling connection between tear and Mullen is sometimes so confused, and it is so simple when you come to think of it in terms of sheet density.

VAN DEN AKKER. Jim, I disagree with you. It's possible, is it not, to have a sheet of high density comprised of low tensile strength fibers and a sheet of equal density comprised of high tensile strength fibers? Now, which sheet will have the higher tearing strength?

CLARK. The one with the high tensile fibers.

VAN DEN AKKER. But they have the same density.

CLARK. It's true, but I'm not saying that density is all of it. I'm saying that it is a factor.

VAN DEN AKKER. All right. Now, the theory that you speak of is an interesting one, and we should always keep it in mind about all materials. It is a theory as applied to paper that was worked out by Brecht and Imset many years ago. It has to do with stress concentration at the zone of rupture when you tear the material. As you say, as the material becomes more brittle and less extensible, it is easier to tear.

CLARK. The load is applied to the tearing point in a more concentrated manner.

VAN DEN AKKER. Yes, and if the material is more extensible, such as when you impregnate paper with latex (artificial leather), the tearing strength goes up enormously, on this theory, because the stress becomes more diffused. For a given tearing force, the local stress is lower. On the basis of the other theory, the energy requirement is greater for pulling out the fibers. Now, I think that both theories should be kept in mind. These aren't opposing theories at all, they are just different ways of looking at the same thing.

CLARK. Agreed.

CAMPBELL. Van, isn't what you're saying equivalent, by analogy, to the business of cutting a piece of paper or anything else with a sharp knife or with a dull knife? In the case of the dense sheet, or the strong sheet, you are cutting with the sharp knife. And in the more diffused sort of sheet, you are cutting with a very dull knife, and it takes a whole lot more work to cut with a dull knife.

CARTER WATSON (Puget Sound Pulp and Timber). I direct this question to the members of The Institute of Paper Chemistry and to Dr. Clark. It seems that a fundamental question has come up. It's one that has been in the literature before, but I've never head it aired on the ground and here is a good opportunity. Let me start by saying that a moment ago Dr. Clark brought up the subject of apparent sheet density and how it could be correlated with tearing strength. Prior to this, he brought up apparent sheet density and its correlation with other physical properties of the sheet, as has been under investigation some 30 years, I believe. Now, for a number of years, apparent sheet density was thought of as being perhaps one of the criteria for evaluating pulp. In other words, this is a basis where we have in a unit volume a given number of fibers. We are all interested in knowing whether this material that went into making this sheet is better than that material that went into making that sheet. It appeared to me initially that the apparent density was an important factor. In other words, we have so many fibers which are in this one sheet per unit volume, and we have so many fibers in that sheet per unit volume. As a matter of fact, so much so that if you take any pulp from any region and hydrate it in any manner, and plot a particular factor versus sheet density, you will find that most of your pulps made on the same process in the same region all will fall on a similar curve within statistical limits. Now, it seems to me that it would appear that Dr. Clark would be right in this matter, that this does indicate the fundamental nature of density, and yet in a number of reports that I have gotten, it is classed by the Institute as not being of a fundamental nature. I believe what they mean by this is that there are perhaps other factors that are more important. But this is the question I would like to have cleared up in my own mind right now. What is the importance of apparent sheet density in making these correlations, and is it classed as a fundamental characteristic of a sheet?

CLARK. Unfortunately this whole matter of apparent sheet density and specific volume has been awfully snarled up because of poor measurements. The test is very insensitive. It's an accurate test, but it's an insensitive one, and one has to use great care in determining it. The sheets have to be well made, well pressed, and then you measure gently the thickness of five sheets. And if you do it in that manner—you get an arbitrary figure because it depends on the pressing and what you have—but using TAPPI Standard test sheets you get a figure that in my opinion is one of the most valuable of all tests. And the reason why it has been discredited is the fact that it has been so difficult to measure accurately—people don't spend the time to do it properly. And in the recent work at the Institute, if I may speak for them, they threw the density test out, and a little while later they brought it in again. I think that's good. I think it should be there. It's a most important property because of these mathematical relationships. Now, there is another interesting thing about sheet density. I've mentioned it before many times, but there has been so little work done on it. And that is if you plot the logarithm of the input of the beating energy against sheet density, or better yet the inverse specific volume, you get a straight line. And this is a most valuable tool. When you get a beating curve, and if you plot the specific volume of the test sheets against the logarithm of the beating time, with any apparatus at all, you should get a straight line. And the slope of that straight line should be the same for almost any pulp, provided it is unbeaten to start with. Then, again, these relationships that Doughty brought about the burst being proportional to the density, the tensile being proportional to the density, the tear being inversely proportional to the density, I have confirmed them, and no one has disputed them, but you fellows aren't using them—you're using freeness. Why don't you use density instead?

VAN DEN AKKER. On the point of whether it's fundamental or not, there is only one thing that I would insist on, and that is that we regard sheet density as a dependent variable, not an independent variable. We shouldn't look upon it as an independent variable any more than we should freeness.

CLARK. I quite agree that it is a dependent variable. As a matter of fact, all of these variables are dependent, but to my mind, the sheet density is a most important property because it is a very good measure of the bruising effect in beating. Any beater will bruise the fibers, and a measurement of that degree of bruising is the sheet density. You will find, as I mentioned just now, that most any kind of beater will apparently beat any kind of pulp at a more or less uniform rate. And, I think, that the more you look into this sheet density, you will find it is a most interesting test—surely it isn't fundamental—but it is one of the most valuable tests we have and should be the basis for comparing, I think, all of our results. Because if you have two sheets made from two different pulps and they are of the same density, then you can swear that, if one sheet is stronger than another, that is the better pulp without any equivocation at all. If you have two sheets beaten to the same freeness, and one is stronger than the other, you really have no idea whether one pulp is better or worse—you just take a guess at it. The chances are that it will be better if it is stronger at the same freeness, but you've no guarantee. That's why I like density so well. It's a reliable test.

WHITNEY. I would just like to add that, as Van said, the apparent density of the sheet is certainly a dependent property, but it's a very important one. It depends upon several things. We haven't said much today about wet fiber flexibility and conformability, but I think this is extremely important. This is one of the factors which has a great deal to do with density in the dry sheet. Certainly the number of bonds and the intensity of the bonds have to do with the density—how much the sheet "springs back" when it dries depends upon the degree of bonding in the sheet. Density is a complex thing, but it is a significant manifestation of some factors which we think are very fundamental in bonding. I'd even go so far as to say that density is a much better parameter to plot beating results against than freeness. I expected Jim to say that this morning when Dr. Thomas gave his paper.

Well, it's 5:00 o'clock and we've been going three hours. Does anyone have anything further to say? If not, I think that the time has come to call a halt. I want to thank the young ladies who handled the microphones, our public address man over there, and particularly, of course, the panel members. They have been awfully good sports. They have had to take quite a bit of ribbing this afternoon, and have done it in very fine shape. This has been instructive for us, and I hope it's been interesting for you. Thanks for coming. The meeting is adjourned.

# Chemical Methods Session II

*Proceedings of the 44th Annual Meeting of TAPPI, Feb. 25, 1959*

The Second Chemical Methods Session of the Annual Meeting of the Technical Association of the Paper and Pulp Industry, convened at 2 o'clock in the West Ballroom of the Hotel Commodore, New York, N. Y., Dr. W. M. Baldwin, Tennessee Eastman Co., presiding.

Chairman Baldwin: Gentlemen, I welcome you to this discussion session on Cellulose Color. It was suggested during our recent ASTM D-23 Cellulose Committee meeting at Chicago this past September. At that time, during our discussions of chemical methods, it was decided that we should plan to meet at this time in conjunction with the TAPPI-ACS-ASTM Chemical Methods Symposium for the purpose of discussing the various problems encountered in the past related to evaluating cellulose color. It was thought that in this manner, we might determine our future course of action in a more representative manner based on the stated views, opinions, and comments expressed by you here today rather than by first formulating some specific methods and then going through lengthy test approval programs by correspondence. In order to obtain a rather wide and broad outlook based on extensive experience and a diversity of interests, the discussion has been planned on a basis of a full and free participation by all of those present here today.

The program outline based on previous work of the Committee has been circulated and lists the various proposed subject topics for our consideration. With respect to Part II and III of the program outline, our moderators, Dr. Plunguian and Mr. Partridge will present the topics to us; various individuals will contribute their experience and knowledge regarding the subject and others are invited to follow up the opening comments with questions and answers regarding their individual opinions and views.

Prior to September of 1957, with J. A. Mitchell as chairman of this Color Task Group, it had been concluded from various polls, questionnaires, annual meetings, and general correspondence that a definite need existed for some standardization on both of the following:

1. A method of characterizing the color (whether "brightness" or "whiteness") of a reformed cellulose sheet or derivative end product.
2. A method for measuring the color of cellulose and derivatives in solution or by extraction, doping, etc., whereby the "true" or "intrinsic" physical color of the material might be classified.

In view of the difficulty experienced in securing agreement among the members of the D-23 Committee at that time, it was decided that our attentions should be focused on the formulation of a tentative proposal to cover the reformed sheet classification procedure and cover the other solution, etc., problems later. Fortunately, as ASTM method for "brightness" (ASTM D 985–50) was already on the books under the the jurisdiction of the Committee D6 on Pulp and Paper. This procedure was identical to the well-known TAPPI Standard T 217 m.

In addition to the "brightness" method, a still more recently developed method for classifying observer color had been proposed, namely the "whiteness" of a cellulose or derivative test specimen. It is in this regard that I recently mailed to most of you here today a tentative proposal for measurement of the "whiteness" of cellulose. If you have had time to read the proposal, I would like to know your feelings at this time as to whether or not it is felt that the concept is worth pursuing and if it is worth while as a tentative addition to our ASTM Standards. This proposed procedure is not meant to be a rapid short-cut method but rather a standard one completely capable of classifying cellulose and derivative reflectance color values in terms of "whiteness." Let me mention to those present whom I mistakenly overlooked because of my incomplete mailing list or change of address, that I have extra copies of my letter and the proposed method for those present who desire them.

I want to emphasize here that the method is in no way intended to replace or supersede previously standardized methods concerning the measurement of "brightness." It is not intended that it should conflict with brightness measurements.

The term "whiteness" may be defined as a value calculated from data obtained by calibrated instrumentation against standards over the visible range. It is calculated relative to magnesium oxide standard or others using the Judd method of color difference and utilizing the Adams equation. In addition, the variations of Nickerson and others, have been incorporated into this type of calculation.

Let me emphasize that we don't propose that this is the answer to all our problems nor that it will adequately cover every situation, but we are making this proposal with the understanding that if the majority of the people here and in our ASTM Committee D-23 and in the TAPPI Chemical Methods Committee feel there is a need for it, we will pursue it. If there isn't any need for it, we will forget it.

Does anyone have any comments to make on this?

Chairman Baldwin: Have I made this clear enough so that you feel such a method might be worth while or worth pursuing? May I ask how many of you received a copy of this method prior to this meeting?

[A count was taken of hands raised.]

I know that all of you didn't necessarily get a chance to go over it, but of those who did receive it, what did you think about it?

Dr. Kenneth A. Kuiken (The Buckeye Cellulose Corp.): We are definitely interested in cooperating in a study of this type. It is not my purpose to discuss the program but to submit two questions concerning things that would be of interest to us in full development of the program.

First, is the use of an instrument as expensive as the one described really necessary? We have a different type of tristimulus instrument, and I would think that the program ought to be designed to include other types of instrumentation.

Then, we would like to raise the question whether whiteness is always the thing we want to measure. Maybe yellowness would have more meaning to some people.

Chairman Baldwin: Thank you, Ken. I want to add a few comments from the floor before we discuss these specific questions.

To be specific, two people replied to my letter concerning these proposals which I sent to some 50 individuals. In their reply Dr. Sutherland, in conjunction with Dr. Hamley of Industrial Cellulose Research, Ltd. made some very pertinent suggestions right along the same lines as Ken has suggested, in that we expand this whiteness proposal to include in other color expressions and variables, I mean factors, to describe

the color more adequately than just by "whiteness." They suggested that in addition to the "whiteness" value calculated on the basis of this fundamental relationship, that we also add the Munsell values, and at the same time, in addition to that, add I.C.I. values for dominant wavelengths and the spectral purity and the "whiteness."

If we do this, this will be a method where we take in all the systems, and it would certainly, I would think, adequately characterize the sample in terms of whether it was white or exactly whatever it was.

We would have a whiteness, and at the same time we would have also the corresponding values for hue and saturation and chroma, etc., to completely define the color.

What is the feeling of the group on this? I believe that any instrument capable of yielding tristimulus values or any instrument capable of yielding data which can be converted into tristimulus data, would be satisfactory.

We aren't saying it ought to be a G.E. spectrophotometer at $15,000 or whatever they cost.

T. L. Kirtley (Hercules Powder Co.): I would just like to comment a little bit along the lines of what Dr. Kuiken mentioned on the yellowness question.

We have found that by-and-large brightness as measured in the TAPPI method does not correlate very well with derivative color. We have for many years used another system in which we measured yellowness of a pulp. This yellowness can be expressed using the I.C.I. system of tristimulus values. When you plot the $X$ and $Y$ tristimulus values, you find for a great variety of both wood and linter pulps, that these fall on a common locus. The dominant wavelengths for most of them is right around 577 $\mu$. Thus the yellowness may be expressed as per cent excitation purity based on the illuminant used and in the normal dominant wavelength. That makes a convenient system which can be applied to a great variety of materials. This has been described in the literature by Osborne and Kenyon [*Ind. Eng. Chem.* 18, No. 9: 523 (1946)].

I am not sure of what "whiteness" means in terms of final product properties. It may be that it is a very good system, and it may measure something that yellowness does not. I think both of them should be looked at very carefully. As regards the type of instrumentation, we have used the General Electric recording spectrophotometer as the primary instrument, but we have used another instrument for control use, which is very much less expensive, and which is very satisfactory.

We have not used the full tristimulus specification in that case, but have used a single number specification which is similar to the one proposed by Dr. Baldwin here.

Chairman Baldwin: Thank you, Tom. I didn't mean to make this proposal with the idea in mind of going into a very lengthy discussion of all the aspects here. Because actually this is something that has more or less been decided in the past, that we should try to pursue, and granted I don't know that the "whiteness" value we get from a reformed sheet of cellulose means anything at all, any more than I know that a brightness value or any other value means anything at all, and I would just like to say this: The objective of such a method would be to formulate a standard procedure whereby a certain fundamental characteristic color, whether it is "whiteness" or whatever it may be, can be established, such that we can evaluate both raw material and end-product color, if it is going to be a white flake or a yarn or what-have-you.

We would like to be using the same fundamental approach in correlating these values, rather than having one running one way and one another, if we can get around it.

That is just the way I think most of the past thinking has gone, and so what we want is for you people to be thinking about this while we move on to the other parts of the program. At the end of the program, I would like to come back and get the consensus on whether or not the people here this afternoon think that it is worth while to pursue this with the additional improvements of adding, say, the Munsell characterization or the I.C.I. dominant wavelengths spectral purity, etc., concepts.

If you think this is worth while, we will try to set up a tentative standard and test it and see what we get.

Later the committees that are responsible for the various end-products, such as cellulose esters and ethers, inorganic esters, can work out their own programs for correlation of end-product quality or color, in terms of this basic cellulose color.

In order to move on to the other section, I have "Characterization of Cellulose Color" down here on my topic outline as the first topic and I have already gone into how in the past, the committee through questionnaires got around to determining what we needed, and went into the reformed sheet color question. I think we just about have that question settled because ASTM had a pretty nice method on the books concerning brightness.

This is ASTM D985, which is similar to the TAPPI Standard.

In addition to that, if a whiteness value is thought to be desirable, we shall have one. If not, we will not have one.

The second problem, which is the major problem, is the one in which the group thought a method should be presented or set up for evaluating the solution color of cellulose. This solution color could be a color of cellulose dispersed in some solvent or could be an extractive color.

I believe all of us here will agree that the determination of cellulose solution color is a big order, and how in the past it has been beset continually by disagreements and controversies and an inability of the people involved in the qeustion to get together on exactly how to accomplish it.

In view of this, we wanted to have this discussion. We have broken down the problem into two parts, simply, that of how we shall prepare a cellulose sample for color evaluation, as listed under Part II of this program, and the other aspect is (Part III) what shall we do with the sample or how shall we measure it and characterize it when we get it.

I would like to go to Part II with the request that all of you here take an active part in adding your opinions and views to those of the individuals in their discussions of some of these various techniques to be considered. In this way, we hope to derive a consensus on which of these methods might we best devote our attention to informulating some tentative standards.

At this time I will ask Mark Plunguian to come up and moderate Part II on the subject of preparation of cellulose color test samples.

Dr. Mark Plunguian (Hercules Powder Co.): I am going to call on a specific person to handle each one of the topics that has been broken down in the outline. Then, of course, we hope that others will participate with each subdivision of this problem.

The first thing we have here is this cold 72% sulfuric acid method for evaluation of color. I would like to call on our chairman, Dr. McColley, to tell us about it.

Dr. McColley (Celanese Fibers Co.): At Celanese, we have used the transmission of a solution of the pulp in 72% sulfuric acid to characterize the color of the pulp or the impurities in it, in order to give us an idea of what type of derivative it will make. To do that we fluff from 3 to 5 g. of the pulp in a Waring Blendor for just about 5 sec.

We condition the fluff pulp for 24 hr., or overnight in an air-conditioned room or in the same room where we are going to weigh it the next day. Then we weigh 2.0 $\pm$ 0.05 g. of the pulp into a 40 $\times$ 80-mm. weighing bottle. We add 40 ml. of 72% sulfuric acid, which has been chilled in the refrigerator to a temperature of 0° to 8°C. and macerate the sample in the acid with a stirring rod. We place the mixture in the refrigerator for 18 $\pm$ 1 hr., and from time to time we open up the refrigerator and stir the mixture a little bit, leaving the rod right in the bottle. The time in the refrigerator is critical.

We can get a higher or lower average result by raising or lowering the temperature in the refrigerator or by leaving the sample in the refrigerator for a longer or shorter time.

After 18 hr. we take out the bottle and place it in a water bath at 20°C. for 120 ± 5 min. We then measure the per cent transmission of the mixture at 440 mμ in a 1-cm. cell. The time from the moment the sample comes out of the refrigerator until the transmission is measured must not exceed 125 min.

Some comparative data that we have obtained between 10 or 11 different samples and six different laboratories, indicate that reproducibility is about ±2% transmission among all of the laboratories and all of the samples, and that in a given laboratory you expect a standard deviation of about 1% transmission from one sample.

D. Molin (Brown Co.): In this measurement of color, the point is what are you trying to obtain? Is it the amount of residual lignin left in the pulp or is it the resin character, when you measure with 72% sulfuric acid?

Dr. McColley: We haven't attempted to say which it was.

Dr. Heath (The Buckeye Cellulose Corp.): Have you compared the sulfuric acid colors of different types of wood pulps, species of wood, and different processes?

Dr. McColley: No, not the way you mean it. We have used it on only purified wood pulps and cotton linters.

Dr. Heath: I don't have data, but I have an impression that you get a different level of readings for different pulps, and I don't know whether that is significant or not, as far as the end-uses are concerned.

Erik Ringström (Uddeholms Aktiebholag, Skogallsverken, Skoghall, Sweden): We have used it as a measure of residual lignin, but we found that variations in pulps influenced the figure very much. It is probably an effect of both of these factors

Nowadays we don't use that method any more.

It was possible to use it by comparing standard pulp of the same kind and of the same degree of purification. In that way it is possible to follow the bleaching process, for example, but if you go to another kind of pulp, the figures are not comparable.

Mr. Wells (Eastman Kodak Co.): We have used a modification of this method, and you will find a difference in color, depending upon the previous history of the pulp degradation, will appear as sulfuric acid.

Mr. Ringström: I could add, after extraction it was possible to get comparative figures. Such a combined method made it rather time consuming.

Mr. Molin: It seems to me that this method, in our experience, covers a lot of what you might call impurities, in the pulp or in the way it is purified. Another factor, of course, that may affect it is the amount of organic matter that may be in the water.

Dr. Plunguian: You mean impurities, organic impurities?

Mr. Molin: Organic, resins, residual lignins, tannins, in the water, and as one of the previous gentlemen mentioned, if it is overbleached.

Dr. Herbst (Industrial Cellulose Research, Ltd.): It seems to me the difficulty is a semantic one. Are we trying to determine color or trying to determine residual lignin? If we determine color, then we just define the color by the color of the solution. We don't worry about the residual lignin. But if we try to determine residual lignin, this is a difficult problem.

Dr. McColley: I would like to answer him by saying that actually all we are measuring is color. We agree that all sorts of things that are in it will affect it. It is highly empirical. The test must be done exactly the same way every time, in order to get results which will give you some kind of idea of the acetate that the pulp will make.

Mr. Molin: I would like to come back to the original objective of this; are we measuring color or measuring impurities? I have been forced to use the G.E. spectrophotometer quite a bit, and as far as I can see the only way you could interpret color is to look at the recording chart. I mean, there are many ways, and many other means of expressing a figure, but to look at the curve of the samples that you have put under the integral sphere and get the actual recorder refractance at each wavelength, in my opinion that is the easiest and best way of interpreting the color of the samples.

If you are measuring something else, the impurities in there, you will have dips or so on along the curve.

Dr. Plunguian: In other words, what you are saying is you are making some artefacts, that you are not measuring what is present in the original product? You are creating something?

Mr. Molin: If you want to measure color, the G.E. spectrophotometer, the reflectance over the whole wavelength.

Chairman Baldwin: Let me add a few words. I am not trying to end this discussion but it seems to me that we want to measure color, and that we don't know exactly what the color of an absolutely pure cellulose sample will be. It is possible that it will be pure white or, say, a complete blending or transmission of all the wavelengths in equivalent quantities necessary to give us the perfect colorless sample.

I think we are back to terminology or semantics again, that in measuring, we want to do just exactly what was first said, get a solution or a test specimen whereby we can characterize this color, irregardless of the cause or from whence it comes. I think in this procedure Earl pointed out the Celanese or the Columbia method for evaluating their solutions, which is merely just a transmission at one wavelength, and we can get on to that in the second part, in Part III of this discussion, where we want to get into the measurement of the color and the instrument we will use, this can be discussed more fully.

Does this help at all?

Dr. Plunguian: Do you have a comment?

Dr. Rapson (University of Toronto): It seems to me that the suitability of any method of getting cellulose into solution to measure the color must rest solely on whether or not the process for getting the material into solution changes the color. In the case of sulfuric acid, we do know that it will change the color of what appear to be colorless materials. It will produce colored materials, and, therefore, it is highly empirical in any case, and it must be correlated in some way with the yarn color or whatever it is we are finally interested in.

It seems to me in the evaluation of each of these procedures, what we want is a comparison of a wide variety of materials in the acid or whatever it may be, and in the final product. Without such a comparison, I don't see how we can make any evaluation of the method.

Dr. Kuiken: I would like to ask Earl a question. Have you looked at these things at different wavelengths?

Dr. McColley: No.

Dr. Kuiken: I don't have exploratory experience with the sulfuric acid method. However, I do with phosphoric acid. I believe that the same phenomenon is likely to confuse both cases, in the case of purified pulps in phosphoric acid solution, the observed optical density can be identified as a phenomenon. Perhaps you want to measure the scattering components. In any event, color and scattering effects must be distinguished. In my observations, only a very small part if any, of the phosphoric acid response is color.

Dr. Plunguian: Suppose we go on to the next subdivision here, maybe we will bring out some of the general discussion.

At this time I would like to call on Dr. Sutherland from Industrial Cellulose Research Ltd. to tell us about the phosphoric acid method.

Dr. Sutherland: Some years ago we had the need for some such method as this, and we might describe it as intrinsic color.

We first tried the sulfuric acid method and ran into diffi-

culties—found it very hard to reproduce without extremely careful control. That is, the solution was dissolved over considerable time at a low temperature, but the color, or what-have-you, that you are going to measure is not going to be measured at that low temperature, so in the warming up and at the higher temperature, as I think Dr. Rapson pointed out, there is a very appreciable change in the color of the solution.

I went on to try out phosphoric acid, and 85% phosphoric acid solution, I found to be a much more reproducible method, and the method was easier. I could outline this a little bit.

Eighty-five per cent phosphoric acid is used, and the solution is such that you have 10 mg. of cellulose per milliliter. The slurry of the airdried cellulose in phosphoric acid is made up and stirred for over an hour. It is then put away for 18 hr. at a temperature of 35°. A somewhat higher temperature might be used.

It is too slow at 20°, and 60° would be too high. Possibly 40° would be all right.

Then, when this solution is obtained, the absorbency is measured on the DU spectrophotometer in the ultraviolet range. The 220 to 250 $\mu$ range gave a very, very good sort of result, but at 290 $\mu$, sulfite pulps show a peak, and kraft pulps show a point of inflection or a smaller peak, and these give some indication of whatever it is that you want.

Dr. Plunguian: This experience would seem to indicate that phosphoric acid was more reproducible. Does anybody else have any experience with it?

Chairman Baldwin: I would like to ask a question. Is there any charring on continued aging of the materials, or does the material continue to intensify the color?

Dr. Sutherland: The color intensifies, but quite slowly at that temperature.

Dr. Partridge (Brown Co.): May I ask a question. You indicated that the maximum color development is measurable in the UV. I am wondering if what we are interested in is the UV or the visible?

Dr. Plunguian: Aren't you measuring at 290 $\mu$—isn't that going back to—lignin? This, too, gives you this same peak.

Dr. Sutherland: Yes, that would be certain.

Dr. Kuiken: You can't see much color to the naked eye. Short wavelength light is scattered according to the fourth power law. In my work I have not looked at any sulfite pulps.

Chairman Baldwin: Ken, do you think it would interfere with our using the solution as a basis for fundamentally characterizing cellulose color?

Dr. Kuiken: You have to decide whether you want to include scattering effects in the color measurement or want to eliminate them, or want to work out an explanation for them.

Dr. Plunguian: This thing that Dr. Sutherland mentioned about intrinsic, would that go back to the fact that you don't get the scattering?

Dr. Heath: Are these scattering particles filterable?

Dr. Kuiken: We haven't been able to filter them out, but we can centrifuge them out.

Dr. Heath: I don't know whether it would be practical or not.

Chairman Baldwin: It would seem to me it would be best to eliminate this scatter, to set up our procedure to include these effects.

Dr. Kleinert (Pulp and Paper Research Institute of Canada): Recently we terminated an investigation of the hydrolysis of bleached pulps with 72% sulfuric acid in the cold. In particular, the light absorption in the wavelength-range 200 and 500 $\mu$ was studied.

Two absorption maxima were found to exist, one in the short wavelength range, which is related to substances similar to lignin, and another flat one beyond 400 $\mu$, which seems to be caused by substances derived from carbohydrates.

When the pulp, before hydrolysis, was subjected to sodium borohydride reduction, the absorption maximum in the visible light range was practically nonexistent. However, the short wavelength absorption maximum was not affected.

By stepwise bleaching of pulps under very mild conditions (12 to 15 steps), we found indications that bleached pulps of even high brightness may contain small amounts of noncarbohydrate substances related to lignin. Of course, these substances are modified by the bleaching processes; however, they exhibit not only a short wavelength absorption maximum (at 205 $\mu$) but also a carbon content in the range of that found in lingin.

We feel that for the color of bleached pulps at least two different groups of substances, as mentioned, are responsible.

Dr. Plunguian: We will go on to the next subdivision. Under the outline of Dr. Baldwin's discussion, which is printed here, we have types of reagents.

Mr. Partridge: I can't say too much about it at this point because we have not gone into it too fully, but Dr. Morse, one of our group in Berlin, working from Dr. Jayme's original paper has prepared some cadoxen reagent (cadmium ethylenediamine) and used it to dissolve cellulose and measured the color of the solution with the Beckman spectrophotometer.

We have attempted in a very preliminary way to correlate this with cellophane film color, with, I think, reasonably good results. The reagent is relatively easily prepared. The solutions are simple to prepare, and I believe that the whole process is complete in an hour or so.

I am not prepared to comment too much on the stability, or whether color development continues over 24- or 48-hr. periods. All I can say now is that solutions can be prepared and the color measured. From our preliminary work there is a correlation between that and film color.

Chairman Baldwin: I want to ask one question while you are still there. Does the cellulose completely dissolve and is the sample completely dispersed?

Dr. Partridge: The solutions appear to be clear. There may be a small amount of haze. There is no fiber left. We have done both pulp and cellophane film with apparently good success.

Dr. Plunguian: Has anybody else had any experience with this solvent or is there any comment on that? Apparently it is too new to have gotten around very much.

We will go on to the next section, and that is actually what you might call approaching end-use methods, where you want to evaluate the color of the raw material by preparing on a small scale an actual derivative. For that, I would like to call on Dr. Baldwin to tell us something about Tennessee Eastman's experience.

Chairman Baldwin: I don't want to go into the method extensively. However, it is simply a very carefully standardized procedure for carrying out a bottle acetylation, and in this case we take conditioned samples of cellulose and subject them, under controlled conditions of temperature and catalyst ($H_2SO_4$), to acetic anhydride and acetic acid and carry out an acetylation in the sample bottle, the same bottle we will use in our color evaluation.

I think the method is fairly well known. I think other companies use similar methods in some instances and others don't.

All of our suppliers are aware of this method, and in general in the past it has been quite useful in classifying our raw materials. It doesn't take in every factor as far as the relationship of this bottle color to end-product color is concerned, in that bottle color does not always correlate directly with, say, yarn color or other end-product color in every case.

However, for any one manufacturer or any one producer of pulp or lint, an individual type of pulp product will usually be correlated with bottle acetylation color. If the color goes up, the end-product color will go up. We can't compare different pulps manufactured by different people.

Dr. Plunguian: Does anybody else have any experience with that type of test?

Dr. Heath: Wouldn't the haze be a big problem here? Compared to phosphoric acid, there would be a lot more haze.

Chairman Baldwin: That is right. I didn't go into any details of what the solutions look like. Actually in bottle acetylation, we are producing a cellulose derivative in acetic acid, and, true enough, in most solutions there is a definite haze. This is not so bad in the case of lint, but in the case of pulp it is considerable. Most all grades of pulp produce esters which in acetic acid solution possess high haze levels. This complicates the color evaluation process. I hope we will have some very competent information on that in the next section, and I would rather leave the haze problem until then.

If anybody else has any information on it, let me know about it.

Mr. DeBow (Brown Co.): If you find, for instance, in two different types of a pulp that the end products are the same, and yet your tests, your bottle aspiration, acetylation tests, one shows a different coloring, have you ever been able to track down what are the offending characters to give you that color, and yet it is removable apparently in the process?

Chairman Baldwin: That is a good question, and I will say "no" in reply to that. We have tried to do that, I believe, not me, personally, but I think it has been looked into, and I think without success.

In other words, the color forming impurities, if you will, that are present, are present in such small quantities as to be practically impossible or very difficult to identify.

Mr. DeBow: There is a lot of emphasis many times on residual lignin, and I am wondering if that is the offending character or is it something else.

Dr. Plunguian: It makes you wonder whether it is really lignin or whether it may be something else. I don't know if I was convinced.

Chairman Baldwin: I personally think it is lignin.

Dr. Kraessig: I would like to ask one question: Do you use as an indication of color the widely used difference between two absorbencies at two wavelengths, or do you use a different parameter?

Chairman Baldwin: You mean in our bottle acetylation? That is another thing we will get into in the next section.

Dr. Kraessig: I think you are thinking about the same thing I am.

Dr. Sutherland: I could say that I believe that the phosphoric acid solution measured in a range of 400 to 440 checks very well with the acetate test that was described by Dr. Baldwin.

Mr. Plunguian: You mean the standard bottle acetylation test?

Dr. Sutherland: Yes.

Frank Charles (Industrial Cellulose Research, Ltd.): We measure color and haze on the acetic acid solution of the triacetate and also on the acetone solutions of the secondary acetate. We use the method that Dr. Kraessig has mentioned, based on transmission at the two different wavelengths, and we also use the Tennessee Eastman method with permanent color and turbidity standards. We could not say that there is any necessary correlation between the triacetate color, the secondary acetate color in acetone, and the color of the end product; so why are we trying to measure something which has no real value commercially?

Maybe there is a reason, but I want to put this question: What is the use of measuring something which differs according to the acetylation procedure you use? I think the Tennessee Eastman procedure is very good for Tennessee Eastman and the Hercules procedure for Hercules, but they don't always agree.

Another thing, if you are going to talk about the triacetate color, you get away from the haze problem easily enough by the correct acetylation condition, by your catalyst and pre treatment.

You can get away from the haze, and so it is possible to develop a test which would be free from haze and measure only color. It is valuable for each group that is interested in it to have their way of characterizing their materials, but is there a necessity for a universal method in this respect, seeing that the result is so dependent upon the process which you use and all the processes of acetylation are so very different, as you know?

Dr. Plunguian: Perhaps we ought to reserve that discussion for the end. Shall we wait until perhaps we have reviewed the other methods, and then it should be very interesting to take that up?

Dr. Stern: I have a suggestion which may be very wild. Trithiocarbonate can be removed from viscose by exchange.

Mr. Charles: They call such purified viscose "white" viscose, but it is actually light-green and would not do for color measurement.

Mr. Partridge: It has a very strong absorption in the UV, 305 I believe it is.

Mr. Charles: Hydroxyethyl cellulose is another suggestion along the same lines; I don't think I would try it, but it would be better than the xanthate.

Dr. Heath: In connection with what Mr. Charles has said, the need for measuring the color, it seems to me that we would like to have a method of measuring what Dr. Sutherland has called the intrinsic color of the pulp in a way which would least disturb that color. Then we would have a standard color of pulp, which might be related by various people to their end-product, to see if there were any correlation between pulp color and end-product color.

Of course, that will be different. The procedures will be different for each mill and for each type of product, but we would have something to start with on the pulp color that would be the same.

Dr. Plunguian: In other words, what you are saying is we ought to have a method which would dissolve it under the mildest possible conditions and that wouldn't itself add anything to the intrinsic color?

Dr. Heath: That is the ideal situation as I see it.

Dr. Plunguian: Then we would like to go on to the extraction procedures as distinct from the solution procedures for measuring color. Here again I would like to call on Dr. McColley to tell us something about these aqueous caustic extractions, which I believe the Celanese experience is tied in with the sulfuric acid method.

Dr. McColley: This is a hot extraction, what we call a CY procedure, in which we take 10 g. of pulp, put it in a 250-ml. Erlenmeyer flask, add 200 ml. of 3% NaOH, cover with a 150-ml. beaker, and put the flask in an autoclave. After running in steam until the air is expelled, we close the valve and let the stream pressure rise. As soon as the pressure reaches 19 lb., we note the time and heat for 30 ± 0.5 min. as measured by a stopwatch, at 20 ± 1 p.s.i.g.

Then we turn off the steam and allow the apparatus and contents to cool for 30 min. The pressure drops to zero in about five or six minutes. Since the final measurement is very sensitive to the pressure and the time, these are controlled very carefully.

After being in the autoclave for 1 hr. the flask is removed and the mixture is filtered through a coarse glass crucible. Since the flask is hot, it is handled with asbestos gloves. The filtrate is allowed to stand 1 hr. at about 25°C. (room temperature). From the moment it is removed from the autoclave, the total time is between 65 and 85 min.

We measure the per cent transmission of the filtrate in a 2-cm. cell at 440 $\mu$ and also at 640 $\mu$. We subtract the transmission at 440 from the transmission at 640, and divide by the transmission at 640, to obtain a quotient which we call a "yellowness coefficient."

The standard deviation of this test for eight separate determinations of the same pulp, in one trial was 0.015. Where we have had six laboratories cooperate in running this test, we have found the average of one laboratory to be 0.07 higher than average for the six. The average of another laboratory was 0.06 lower than the average of the six.

The standard deviation of the deviates of each sample from the mean for a given laboratory varied from 0.01 to 0.05.

Dr. Plunguian: Does anybody else have experience with such methods of fusing hot caustic? I suppose that it is really related to the so-called soda soluble, which a lot of people have used.

Dr. McColley: We used to do a 3% soda solubility. We got into this Cy test by using the hot filtrate from this solubility test.

Mr. Charles: I would think that with that method you would certainly not be measuring pulp color. You would be measuring very much the color which had been produced, would you not? That is not the original pulp color.

Dr. McColley: We produce this color.

Mr. Charles: It is largely produced; if you take for instance the boiling 7% NaOH soluble test, the longer you cook it, the more you get dissolved. In the extract there is a question of time, and I would think that such a test would not exactly be a pulp color test.

Dr. McColley: It is a characterization test that is very empirical. Between 10 and 20 p.s.i.g. about 0.01 Cy unit is added for each pound of pressure. The rate of change in yellowness coefficient is about 0.0070 unit per minute for the first 30 min. and then levels off to about 0.0015 unit per minute. It is necessary to maintain all the test conditions constant.

Mr. Charles: Do you have any figures on the highest grade of cotton linters, let us say, the purest grade of materials? It wouldn't be zero.

Dr. McColley: The best we have run is about 0.18.

Dr. McColley: We would expect to get somewhere from 0.2 to 0.3 for a good grade of cotton linters.

Dr. Rapson: I wonder if you tried to correlate this Cy number with carbonyl content of the pulp? I think you will find a good relation between the carbonyl group content and the color formed because this is really measuring the carbonyl groups. It is no wonder that you wouldn't get a good figure for cotton in this case because the number of carbonyl groups introduced in the purification of cotton is relatively small compared with those introduced in pulp manufacture.

One of the objects of high quality pulp manufacture is to eliminate as much as possible the carbonyl group content of the pulp. I think this is related to the color of the end-product too. I think the color that is formed in this test is proportional to, in some fashion, the color formation in the making of viscose rayon and in acetate.

Dr. Plunguian: In other words, it may be an artefact, but still one pulp might have more of those groups than another, and it still may be meaningful, even if empirical.

Dr. Kraessig: I agree with Mr. Charles and also with Dr. Rapson that we cannot consider the results of these tests as a function of the color of the pulp. We know from the work of Kenner and Richards and also from work done in Sweden, that hot alkali forms absorbing compounds.

I do not remember if there are bands in the visible region. I would not be astonished that these compounds give color, and we should be aware that this color is not necessarily related to the color of the pulp or the color of the end product.

Mr. Partridge: I wanted to ask Dr. McColley if a good correlation exists between this hot soda solubility test and the cold sulfuric acid. I think this is perhaps a pertinent field to explore.

Dr. McColley: Yes, there is a correlation, but I can't put it to you in numbers. However, it was pointed out that there is a very good correlation between Cy and the color, say, of plastic made from it.

Mr. Ringstrom: I want to ask the Board if somebody here has any experience if the properties of the caustic extract correlates with the viscose process? It seems to me that it could be quite a realistic test because it is just the same treatment that the viscose industry is doing, and the color formed in the liquid has material which goes further into the process together with the residual press liquor. Some of the rayon producers of Europe use this process to try to correlate the color of the liquor with the color of the finished product.

I want to put the question and ask if anybody has any experience, that is, about the use of cold caustic for the evaluation of color.

Mr. Charles: Mr. Ringström, you are quite correct, that very often there is a correlation, but very often there is not. Here again, what is the use of measuring something which has no correlation? We measure it, but I don't think it is anything for standardizing a method on.

Mr. Ringstrom: I quite agree, but nevertheless some viscose producers use such methods for evaluation of pulp. It would, therefore, be of a certain interest to carry on with some experiments to clear this question.

Mr. Charles: Sometimes yes, and sometimes not.

Dr. Kleinert: We studied alkali extraction of bleached pulps and determined the absorption spectra of the extraction liquors.

Extraction at room temperature and at 100°C. was investigated. In particular, mercerization studies of dissolving pulps were carried out.

If the initial pulps were mercerized in a slurry process, the extraction liquors were found to be colored to a varying extent, the latter having some relationship to the oxidation degree of the extractives. However, if the initial pulps were mercerized after reduction with sodium borohydride, the extraction liquors obtained were nearly colorless.

It might be of interest to mention that the color of commercial alkali cellulose was found to be dependent not only on the initial pulp material but also on the process of mercerization and aging used. In press steeping, only part of the chromogenic groups was found to be removed, and an appreciable amount newly formed in the air-aging. If slurry mercerization was used with additions of hydrogen peroxide, most of the chromogenic groups were removed and only little formed in the pulp degradation, the alkali cellulose formed exhibiting very little coloration.

A series of experiments was also carried out in which alkali cellulose was produced in slurry mercerization and the pressed alkali cellulose after 24 or 48 hr. air-aging was extracted with pure 10% sodium hydroxide solution. With increasing time of aging, the extractives obtained exhibited an increase in coloration and degree of oxidation. This indicates that formation of chromogenic groups during aging is related to pulp oxidation.

In another series of investigations, the color and light absorption of the extractives obtained from bleached pulps (dissolving grade) by hot alkali (1% NaOH) extraction was studied. When boiling time was extended, the extraction liquors turned from an initial light color to an increasingly darker shade. It would be interesting to determine what substances produce the dark color. Unfortunately, the extraction liquors contain a variety of colored substances. We are trying to isolate distinct compounds from the extractives for a study of their chromogenic groups. Although hot alkali extraction cannot be considered a true extraction but rather a degradation process, it is felt that the colored substances obtained from bleached pulps by cold or hot alkali extraction are of a similar nature.

Mr. Kirtley (Hercules Powder Co.): In that connection

we have also done some work in studying the soda solubility in 7% caustic in relation to time, and, of course, you find that it is time-related.

In the presence of oxygen, it reaches a state after about 6 hr. at which the rate of increase in soda solubility is constant or the noted color development is also constant.

However, if you carry that out in the absence of oxygen by evaluating the flask to start with and flushing it carefully, you will find that after about 5 or 6 hr. the extract levels out to a constant color.

Dr. Plunguian: If there are no more questions on hot alkali extraction, we would like to go on to other systems of extraction. The first one is that of hot acetic acid. I will call on Dr. Baldwin to tell us something about Eastman's experience.

Chairman Baldwin: At Tennessee Eastman, a test was developed utilizing acetic acid extraction in an attempt to solve some of our problems related to our being unable to duplicate the Celanese hot caustic extraction procedure.

What we did simply was to take a certain quantity of cellulose, which had been dried, of course, and just immersed the sample in the highest grade acetic acid we could get, +99% pure, and hold it at a temperature of 200°F. for some 6 hr.

If anyone wants the method, I can give you the specific details on it, but I don't want to take any more time, except to say that at the end of this time, by filtration of the solution, one observes a color, yellow, which can be evaluated in terms of the same Cy concept described by Dr. McColley. This acetic acid value correlates with caustic Cy color.

I have been informed that the people at Buckeye also found that. Merle, didn't you say these tie in right well, both the acetic and the Cy caustic?

Dr. Heath: Yes, we found they were related.

Chairman Baldwin: I would also like to add that all these methods that we are discussing have been put forth primarily for our discussion, and it certainly is gratifying that we have had the discussion we have had.

None of these are being pushed as the best method or technique for obtaining cellulose solution color. We want to try to get the best, if there is any best method.

I will just hurriedly answer one of the questions about the Eastman bottle acetylation procedure. We are not completely satisfied with it ourselves, and we certainly would like to find the best method possible to determine the color of our end-product as it is related to the color of our raw materials. I might also add here, in some rebuttal, that there is a definite relationship in most instances between bottle acetylation and end-product color. It does follow that if you get an extremely high color in bottle acetylation, you will usually get an extremely high color in your end-product.

Of course, there are variations in degrees of this situation. I don't know anybody other than Tennessee Eastman who uses hot acetic acid extraction. It was just included as another extractive procedure for discussion.

Dr. Kuiken: It seems to me that the reason why we have so many approaches to this thing that we call color is that we work under a great variety of conditions with a great variety of products, and we observe color phenomenon. The real problem is to be able to interpret these color phenomena. This is the area that needs to be thoroughly explored. I feel that the most helpful thing someone could do for me would be to tell me how to measure carbonyls which have been suggested to be related to these color phenomena, when they are known to be present at very low levels in the pulp.

I think this is a very important research area, and if someone has something that they would like to support in this area, I would be very happy to hear about it.

Dr. Herbst (Industrial Cellulose Research, Ltd.): I should like to make a comment on the correlation between the two methods. You have two methods to determine color. You get a pretty nice correlation between them, and you conclude that this strengthens the validity of both methods. I should like to suggest that this may not be necessarily true because if you take a range of pulps which have, say, varying lignin contents, they are also likely to have, say, varying hemicellulose contents and varying in the same sense. They differ generally in extent of purification, and consequently, if two methods show correlation with one another, we still cannot be sure they are both good.

Dr. Rapson: I would like to make a general statement about the situation. One would gather from the discussion so far that the matter of color measurement is in a rather chaotic state. There are so many procedures for measuring the color, but I would like to suggest that there is a rough correlation among them all, and that this is due to having a common characteristic or one or two or three common characteristics which affect each of these methods in a little different manner, but in same general direction.

As has been pointed out, if pulps differ widely in the amount of color they will develop in any end-use method, they can be distinguished, I think, by any of these methods. What we are looking for here is a very fine distinction of an order of magnitude that is reaching the limit of sensitivity of our measurement.

Another factor that has to be taken into account is that we are looking at solids when we are examining the pulp, and when we are looking at the film or yarn or cloth or whatever it may be at the other end of the process.

Whenever we look at solids, the impression we get depends not only upon the color absorbing materials present but also upon the nature of the surfaces, the extent of the interfacial area between the solid and the air, and this fact cannot be disregarded.

For example, if we take cotton or wood pulp and beat it in a beater, we know that the color gets poorer. We call it, in the pulp making business, a loss of brightness, or color reversion.

However, through the work we did recently and just presented in January at the Canadian meeting in Montreal [(*Pulp and Paper Magazine of Canada* 60, 6: T167–172 (June, 1949)] we have shown this has nothing whatever to do with the nature of the color bodies in the pulp, but it has only to do with the change in the interfacial area of the dried sheet, and that nothing we could do chemically to the pulp would change the drop in brightness that we would get on beating simply by creating new surface when wet, which decreased the air-fiber interfacial area after drying.

This has to be separated and distinguished from intrinsic colored material when looking at any solid. My interpretation of this is that on beating, by creating new surfaces, which when the pulp is dry, diminish the surface area by interfiber bonding, that due to this decreased surface, there are fewer reflections, more opportunity for transmission through the solids, and the absorbing material is in the solid phase. The absorbing material we are using in any solution method we have been discussing here is present in the solid. It is either there intrinsically, as has been said, or it is formed during the method of preparation.

The color of filaments or films appears darker than the pulp from which it was made because nearly all the reflecting air-fiber surface is eliminated, leaving a large path through the solid for light to be absorbed. It is not an error in the tests because this color appears due to the processes that make the final product, the viscose, rayon, acetate, or whatever it may be. While it is complicated, the factors contributing to the color can be sorted out, and I think that what we have to do is this: I don't think we can separate the measurement of the color from the factors which cause it. If we can find the separate factors which contribute to it, we can improve it.

We have been doing this with pulp for sometime now, and I feel we have improved the product very much.

Dr. Day: I have been a good boy so far. I am not

sure I am at the right meeting. The title was the color of pulp, and we have heard a lot about the color of alkaline degradation solutions and color of solutions from acid hydrolysis, and those are important for certain indications of certain end uses. I agree with Howard, for once. I don't think it necessarily follows, and I think he brought up a very important thing. There is no reflectance of cellulose, or reflectance of the sheets made from cellulose, and our dear old pal, Dr. Munk, spelled it out clearly many years ago. Isn't it possible I am a little inhibited by lack of knowledge? Isn't it possible to rate the pulp according to the absorption coefficient calculated in the famous Dr. Munk manner? When we do an ordinary brightness test, we try and sort of cancel out the effect of this scattering coefficient by specifying very carefully the sheet-making technique, but the pulp maker is stuck with the geometry of the fiber he is working with, and a hardwood sheet with the same absorption coefficient as a softwood sheet may actually be a poorer brightness because of the scattering coefficient being less favorable.

I don't know, from a practical viewpoint, whether it is reasonable to characterize it by the absorption coefficient, but if it can, that comes the closest to being the specific and basic element of color. I will keep quiet from now on.

Dr. Rapson: May I say something following that? I think that is a very important suggestion, and I have been toying with the same idea. I throw it out to all of you for what it is worth. Perhaps we can get rid of the surface and leave only the solid cellulose without dissolving it, and this can be done in one of two ways. I am not sure that it can be done by simple pressure, but a very high pressure in a die is used to make samples for infrared absorption measurements. We have been doing it in our laboratory by mixing the cellulose with potassium bromide. When we press it under great pressure, we get a thing that looks like glass. It can't have these reflecting surfaces or it would reflect. I know we can do it with potassium bromide. If we can press cellulose enough to get a solid, and then measure the intrinsic color directly without dissolving, we would get rid of the artefacts.

Dr. Kraessig: We are doing this at the moment infrared work in these pellets, you still see the fibers. There is one method used by Australian workers. They get complete transparency when they press cellulose alone at very high pressures.

Dr. Rapson: That is what I am suggesting.

Dr. Kraessig: I think this is a very good suggestion, because any dissolution or any chemical treatment is apt to change the cellulose, as we know, up to now, and I think that is a much better attempt, even when you could, say, coat the paper with something, which makes the surface—say you would only press potassium bromide on top, and then make the brightness test. I don't know how potassium bromide might interfere.

Dr. Plunguian: In the Australian method you say that is pure cellulose?

Dr. Kraessig: They take pure cellulose and press it. We have observed that when cellulose is compressed at high pressure, the fine structure is altered. You destroy that, we know for sure. You make the cellulose more amorphous and more transparent. We went to pressures of about 3000 p.s.i.

Dr. Rapson: While pursuing these wild ideas, it just occurred to me that we might find a colorless liquid of the same index of refraction as cellulose and not have to squeeze it. Is there such a material? There must be. All we would have to do is eliminate the air-interface surface by impregnating the cellulose with that material.

Dr. Herbst: I agree with Dr. Rapson and the gentleman in the back whose name I didn't catch, that not to dissolve the cellulose is probably the best way.

I should like to make a suggestion about two instrumental techniques which are available for independently determining both the scattering coefficient and the absorption coefficient. The first is an absolute method, but requires more care. Sheets of known basis weight are prepared and their brightnesses are measured against black and white backgrounds. The Kubelka-Munk theory shows that this makes possible an independent measurement of the absorption and scattering coefficients.

There is also a quick method which does not permit the determination of the absolute value of the scattering coefficient but permits the determination of the ratio of the scattering coefficient of a given pulp to that of a standard pulp.

This involves the blending of the standard pulp and the pulp under investigation in a known ratio and the measurement of the brightness of the resulting sheet. Such a measurement will give the ratio of the scattering coefficients and also the absorption coefficient.

Dr. Plunguian: Are there any more comments on this preparation of samples? If not we have to go on to the methods of measuring color. I would like to summarize in a few words what we have taken up.

It seems that the sulfuric acid method gives certain results, but it is highly empirical. The phosphoric acid method is more reproducible. It seems to be somewhat better, but on the whole it is in the same class.

Then these new solvents, those described by Dr. Jayme seem to have a very useful potential, and to my mind, it would seem to be the mildest, or milder than the high pressure that you have been talking about, or any other pressure which eventually is to get down to this intrinsic color.

Then we discussed the important end-use method, such as making acetate by simplified bottle acetylation, and that correlates between a certain processor and a supplier, but it does not correlate very well with different products and different methods.

There is, of course, the hot caustic Cy test, which is in the same order as the sulfuric acid test, and that is you get very highly empirical results, and it apparently depends on a lot of other things in which you produce color during the test itself. It gets away more from this intrinsic color. Also there is the extraction method such as with acetic acid, which, as I understand, correlates somewhat better with different raw materials and the end-product, but again it is for one particular process of making acetate.

In all of these tests, there seem to be certain factors which hold true all the way, that is such things as carbonyl content. I think it is well agreed it is a factor in all of them, and, of course, it would be very interesting to do fundamental work on that aspect and find out exactly what lies behind it and exactly why we get the color. Finally there are some new methods, perhaps by high pressure, in making the cellulose transparent, in which case it may be possible to measure color.

Now we can go to the second part of this program.

Mr. Partridge: The time is flying. It appears from the discussions that we have had on the first part of this program on methods of preparation of test samples that my job of measuring them is really complicated by the fact that we don't know what we are going to start to measure.

If we could assume that we have a solution, either an extract or a solution of cellulose and impurities in a solvent, or we have a pellet of a mixture of cellulose and KBr, or a mixture of cellulose and oil or just a pressed pellet from which the refraction has been eliminated, how could we best go about measuring and expressing this color?

The discussion of this physical measurement or evaluation of color is divided here into three sections.

The first is a visual comparison. The color of one of these solutions is compared with some known standard reproducible standard. Such a method was described by Jim Mitchell of Tennessee Eastman last year and is published and well known, that of using the combination of a haze standard

and water color standard, and comparing the unknown with a combined haze and color standard against a light source of carefully defined nature.

This is a visual method, depending on the skill and judgment of an operator and probably doesn't warrant very much discussion at this point, unless somebody has a comment they would like to make on it.

The second section is instrumental. It deals with the various types of photometer and spectrophotometers and colorimeters that could be used. There are three general types, filter photometers, simple, narrow-band filter photometers. Photovolt, Lumetron, Color Eye, and so on.

The second are prism or grating type spectrophotometers. They include the G.E., Beckman DU, etc.

The third type is the integrating sphere type spectrophotometer, which Gardner and Hercules make. There is an instrument which we have in our paper division, the Color Eye.

These are equipped to give tristimulus values, which can be converted by the I.C.I system or the Munsell or Judd system, which gives an actual number to hue, chromaticity, and intensity and so on. Would anyone like to comment on the use of filter photometers for the measurement of color and solutions of this nature?

Mr. Kirtley: I would like to comment in a somewhat negative way, that I think that any standard method that is set up should not use the filter photometer, but should use the very best that is available in the way of selection of wave bands. We have had considerable experience, and rather successfully, with using filter photometer for routine color identification, and I think that such instruments can be correlated with a standard instrument.

I do not think it should be the basis of a method.

Mr. DeBow (Brown Co.): I would like to make a comment, not so much on the filter photometer, as the general way this is measured.

Nowadays we have a standard method of using the so-called G.E. brightness tester, they call it. It is about the poorest instrument you can find on the market nowadays to express brightness.

Dr. Day: The Photovolt is worse.

Mr. DeBow: Yes, in many ways, there is a very sharp drawback in the so-called G.E. brightness tester. One of them is the geometric design. The other is the small area of incident light, and the third one is the extremely poor result in the high white range, high brightness range, over, say, 91 or 92.

Dr. Partridge: I think that what we are dealing with or attempting to deal with here is the color of a solution rather than a reflectance measurement on a sheet, and the G.E. is, as I understand it, not applicable to that particular measurement.

I gather from the discussion that the filter photometers should be pretty well eliminated as the instrument to use for that type of measurement.

We go to the next section of prism or grating type spectrophotometers. Would anybody care to talk on this subject a little bit? Does this type of instrument seem to be the one we want to use for this kind of an investigation?

Chairman Baldwin: I would like to ask Ken, since I think he is fairly familiar with the various instruments available, if the Beckman DU, DK 1, or DK 2 instruments are available with the spectral reflectance attachment? Do they have to be modified?

Dr. Kuiken: That is standard.

Chairman Baldwin: In other words, these instruments which we might call fairly common, or at least some of them are fairly common as to be found in most chemical laboratories would be available for evaluating solution spectra, and then they could be adapted to measure spectral reflectance.

Dr. Kuiken: This is correct.

Dr. Rapson: I would assume that anyone who has enough money should be using such an instrument. It is an expensiv thing, but I think the people who are most concerned wit these particular problems consider it important enough t have such instruments and should use them.

Mr. Partridge: One of the things agreed upon in ou discussions was that it would be advantageous, if we didn have to specify the use of too high-priced an instrument, if w could get at the problem by using instruments which ar generally available throughout the industry.

The DU is getting to be pretty much of a standard instru ment in most laboratories, and it can be used for both trans mittance and reflectance. From that, either the straigh DU or the recording model, you can plot a curve, and fro that curve you can calculate by various means the tristimulu values, and from that the chromaticity, and so on.

The third type here are the integrating sphere type spectr photometers, and I think, of these, the Hercules GP is on that you are prepared to talk on a little bit.

Mr. Kirtley: The Hercules general type photometer i not a spectrophotometer. It is a filter photometer, which wa designed about 12 years ago to fill a need which existe then for an instrument that would be just what the nam implies, a general purpose instrument to do a lot of differen kinds of color and haze determinations.

It may be outmoded now. I would certainly think tha we should have a grating type light source, so that we coul narrow down the wavelengths that we use for measurement.

However, it has many desirable features. First let m describe it just a little bit for those who are not familiar wit it.

There is a tungsten light source surrounded by a turre which contains glass filters for wave band selection.

The light then passes through an appropriate lens syste for producing a parallel light beam. The light then passe into a beam splitter compartment in which is mounted glass plate at an angle of 45° to the light beam. This refract a portion of the incident light beam to a photocell mounted o an axis, by means of which the angle between the beam split ter plate and the photocell can be measured.

The light which is transmitted goes on through a samp compartment in which samples can be placed for transmit tance measurements, and then goes on into an integratin sphere, in which you can place samples, and in which i mounted another photocell.

The null method of measurement is used, in which th light reaching the measuring photocell in the sphere i balanced against the light reaching the balancing photocell in the beam splitter compartment, so that at the null poin you have equal intensity of light falling on each of thes matched photocells.

That balance is achieved by means of a shutter in the ligh beam, and by rotating the balancing photocell.

In measurement of pulp color, the sample is placed at th rear aperture of the integrating sphere, so that the ligh beam is normal to the sheet.

As a matter of fact, you can use just a compressed wad o bulk cotton and place it at the aperture. The measurin photocell is so shielded that it cannot view the sample directl but only by scattered light on the sphere.

In this instrument we have found that the surface of th sample is not nearly so critical as it would be in the case o brightness. For example, we can take loose cotton linter pulp, bulk, make a color measurement, and then sheet th same material, and get just about the same value for color Also in the case of the effect of beating on the color, this effec is much reduced when the color is measured in that manner.

I don't know if there is a commercial instrument on th market that corresponds to this, but it seems that perhap some of them could be modified at least to do this job.

Mr. Ringstrom: There is a European instrument mad by Zetss which is a further development of their old instru ment called "Leukometer." I have forgotten the name o

the new one but it is an instrument with an integrated sphere, and brightness measurements are to a very little extent dependent on sheet structures. I am quite sure it is possible also to measure color. In Sweden, the Central Laboratory of the Pulp Industry regularly send out samples checked on their instrument to the different industrial laboratories and they also check the filters regularly.

I think this instrument is now more or less standard over there.

DR. PARTRIDGE: Would this instrument measure both reflectance and transmittance?

MR. RINGSTROM: It is usually used as a reflectance meter for brightness, but I am not so familiar with it that I can answer the question. It is a very good instrument.

DR. KLEINERT: That is the "ELREPHO" instrument?

MR. RINGSTROM: Yes.

MR. KIRTLEY: One more advantage that we have found for an integrating sphere type instrument is in the measurement of colored and hazy solutions, trying to distinguish between the effects of haze and color.

If you place a sample within the integrated sphere, you have essentially eliminated the effect of the scattered light on the color. In our instrument at least, it doesn't do this 100%, but within reasonable accuracy it will separate color and haze.

We recently made a test in which we made up solutions using the APHA color and haze standards. These were mixed in various proportions, and then we made independent haze and color measurements, and they did come out reasonably close to the calculated values.

MR. PARTRIDGE: Would it seem to be the opinion of the meeting that we should use either the DU type or an integrating sphere type? Are there any further comments?

MR. HEATH: I might say that our experience with the integrating sphere type was not very good. We had one which we made, which worked very well with these synthetic mixtures, but on actual solutions, say, cellulose acetate solutions, we got very poor results.

MR. PARTRIDGE: I had one question I would like to ask of somebody: If you use the APHA water standard, and as a haze standard you use fine titanium pigment, instead of the Fuller's earth type of haze particle, you get a suspension which has a reddish brown color.

Would this integrating sphere separate color due to the yellow water standard and this reddish-brown color which you get from fine titanium pigment.

MR. KIRTLEY: I don't know offhand.

MR. PARTRIDGE: This is what I ran into in trying to make up some haze standards, and I wonder if this kind of thing can be separated.

MR. KIRTLEY: I think the ability to separate color and haze depends somewhat on the type of haze that you have present as Merle points out. It is better on some types than others. It also depends on the geometry of the instrument, the relationship of the size of the sample, the size of the sphere, the size of the photocells, I suppose, because you have both wide angle and forward scattering type haze in there.

By the way, this particular type of instrument does have a means of attempting to measure both the forward scattering haze and wide angle scattering haze.

MR. PARTRIDGE: Thank you.

We come to the next section, which is the standard color system classification. In other words, how should we express the results obtained from a spectrophotometric curve or from tristimulus type, $X$, $Y$, $Z$, coefficients?

Shall we express them as parts per million based on water standards or shall we go to the CIE, or I.C.I system, or some other variance? Are there any comments on that?

CHAIRMAN BALDWIN: I think, in the past, as far as the history of the committee is concerned, in the task group on color, it has been the general consensus that we would want to go to a very fundamental system, utilizing tristimulus values and chromaticity coordinates to express the color in terms of, say, the dominant wavelength, luminous reflectance and spectral purity or go to the Munsell system of hue value and chroma.

Therefore, I think that if there is no objection, and if no one has any comments or criticisms, we will just stick to that.

DR. PARTRIDGE: That would be my suggestion. Seeing it is now five minutes to five, I think I should sit down and let you summarize.

CHAIRMAN BALDWIN: I would just like to say that if no one else has anything else to add or detract from what has been said, I want to thank everyone here for his comments.

I even want to thank those not here who contributed so freely in the past to make this discussion possible. I believe this session has helped us considerably.

As usual, it is a complicated situation still unsimplified, but I believe from the discussion heard today we could say that we feel there is a need for a good approach to the characterizing of cellulose color.

I believe that the phosphoric acid and possibly some of the complex forming solvents have been, let us say, recipients of the least criticism, and, therefore, we will try to get together in our committee work, and work out some sensitive standards based on these approaches for submission to our ASTM D-23 and other chemical methods groups for consideration.

As far as the measurement of the color is concerned, I think it has been very obvious that we do need an instrument, at least in the nature of a Beckman, DU, or DK or some prism spectrophotometer, whether it be the G.E. type or what have you. We do need an instrument, which will give us accurately determined reflectance and transmittance tristimulus values from which we can calculate the colors of these materials.

I believe we will want to possibly look into some of the suggestions as regards producing a test specimen by means of pressure or plasticizer addition or the use of some liquid which will eliminate the refractive indices effects on scatter.

Does anybody else have anything to offer? Let me add that I didn't get to ask everybody here what they thought of this "whiteness" procedure that we proposed, and I don't know if we have lost all of the people in disagreement with it or not. Do we want to consider such a proposal, or should we wait for other proposals. Does anyone have any feelings on this?

What about Earl and Ken? Do you think the additions that have been proposed are good?

DR. KUIKEN: We are interested in cooperating.

DR. MCCOLLEY: We will pursue it.

CHAIRMAN BALDWIN: We will, then within our group, attempt to get the best agreement that we can on how to do this and pursue the characterization of cellulose sheet, in terms of some "whiteness" and other values.* I want to thank you again for your contributions.

The meeting now stands adjourned.

**The meeting adjourned at 5:00 p.m.**

* In addition, a solution color method based on either phosphoric acid or Jayme's complexing solvents shall be compared for proposal utilizing specified procedures for fundamental color classification and measurement.

## 14th Alkaline Testing Conference

**Multnomah Hotel**

**Portland, Ore.**

**Aug. 22–24, 1960**

# Primary Defibering of High Yield and Semichemical Pulps

## *"IMPCO" Solvo Fibrilizer Operation at North Carolina Pulp Co.*

J. F. KEYES

At our mill, the North Carolina Pulp Co., Plymouth, N. C., we have in operation the initial pulp mill installation of the IMPCO Solvo fibrilizer. The fibrilizer installation has resulted in a more uniform pulp to our primary disk refiners, reduced the headache of plugging control valves and stock lines, simplified startup, and has reduced the amount of material returned to the blow tank for nesting purposes. The installation has resulted also in less maintenance and reduced horsepower. These features will be discussed later in detail.

When it became necessary to repair or replace part of our existing refining equipment, the officials of North Carolina Pulp Co., and of IMPCO discussed the possibility of using the principle of the IMPCO Solvo pulper for this purpose. We entered into a mutual program for the investigation and subsequent development of the Solvo fibrilizer; this program was successful and the Solvo fibrilizer has been made a permanent part of our system.

The Solvo pulper was invented by Sture Wicksell of Stockholm, and is basically a perforated plate fastened to a highly modified pump impeller rotating in a pump case. Patents were obtained in most of the paper producing countries. This rotor, installed in a vertical position at the base of a vat or tub, proved to be an excellent broke and pump disintegrating apparatus.

We will discuss the pulper design, as it has much in common with the fibrilizer, and influenced our decision to try the concept presented by IMPCO.

I mentioned the fact that basically the Solvo rotor is a perforated plate in the suction of a pump (see Fig. 1). When pulping broke or baled pulp, the undefibered particles pass over the perforated plate and try to enter the holes, drawn by the suction induced by the pump vanes directly below the plate. The centrifugal action, induced by approximately 450 r.p.m. rotation of the rotor, develops a force to throw or move the particle off the plate and up the sides of the vat or tank. Thus, the particle is drawn apart along its easiest shearplane with little or no damage done to the fiber itself. Fiber hydrolysis, if any, is limited to the work done in any ordinary pumping operation.

The pump, which is integral with the unit, will deliver a normal pumping head at pulping consistency. In the high density broke pulper design shown here, you will note a screw conveyor flight on the rotor shaft, which aids pulp movement in the vat and assures continuous feed of pulp with further assurance that all the fiber will receive an equal share of the work put into the unit. In batch operation, the stock is returned back to the vessel through the circulating line, up the outside, and into the top of the vat.

J. F. Keyes, Pulp Mill Superintendent, North Carolina Pulp Co., Plymouth, N. C.

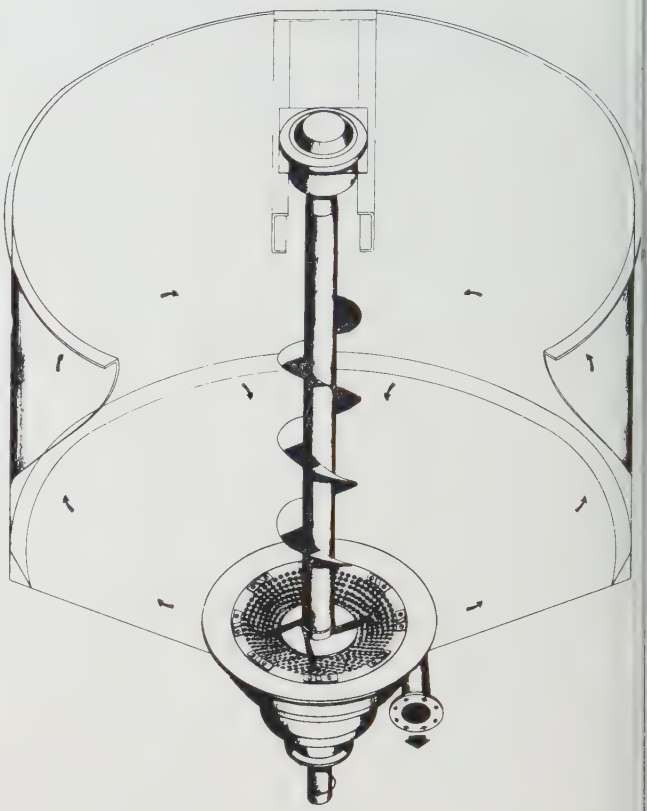

*Fig. 1*

Thus, displacement is obtained in the pulping zone allowing up to 11% consistency on certain grades.

The design provided for our program is designated as a No. 3-25 IMPCO Solvo fibrilizer. The rotor is approximately 35 in. in diameter, and the packing is water cooled. Oversize bearings and heavy shaft fitted with a hard-faced sleeve through the packing box have relieved us from any trouble in the mechanical design. A thrust bearing takes up to 25 p.s.i. blow tank static pressure.

The fibrilizer was located, originally, at the base of the conventional 60° cone bottom blow tank at our NSSC plant. The fibrilizer was installed in parallel with existing equipment in our blow tank in September, 1958. During

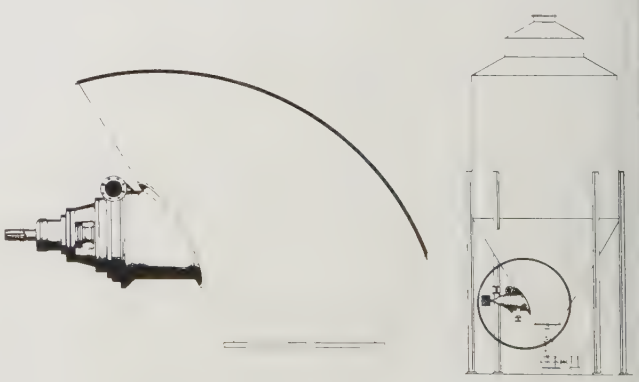

*Fig. 2*

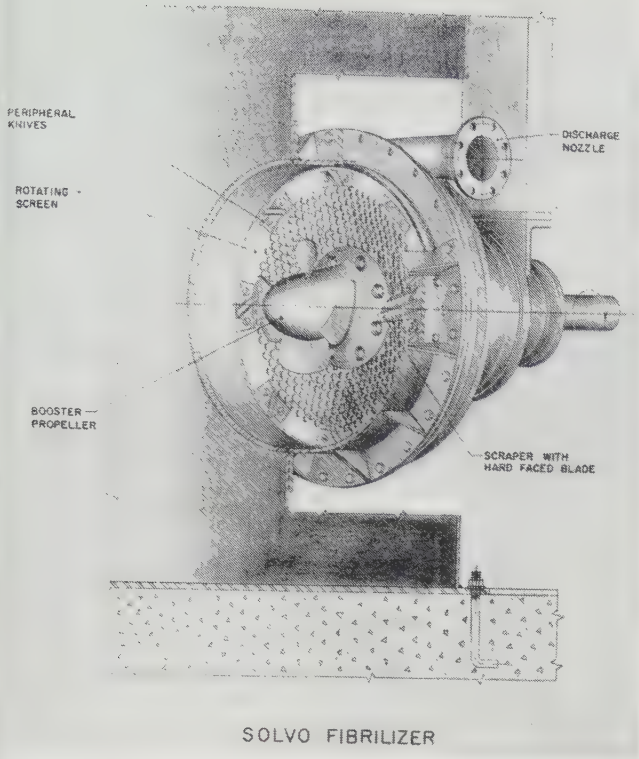


*Fig. 3*

run of pine kraft, it operated for approximately 15 min., at which time we lost our load, and on examining the plate we found it plugged. We changed the holes in the plate from $^3/_8$ to $^1/_2$ in. with no change in operation. On October 2, the holes were again changed to $^7/_8$ in. in diameter and we were able to get some tonnage through the unit but the holes in the plate eventually plugged. We changed the holes from $^7/_8$ to $^7/_8$ by $1^1/_2$ in. by cutting out the adjacent material between two holes; this is the plate that we use at the present time. At the same time, we installed a 300-hp. motor and increased the fibrilizer plate speed from 450 to 550 r.p.m. We were still not able to maintain normal production.

During the first week of October, 1958, a baffle was installed inside the fibrilizer opening, and a steel experimental stationary blade installed to wipe the screen plate; also a propeller was installed on the hub of the fibrilizer in order to

*Fig. 4*

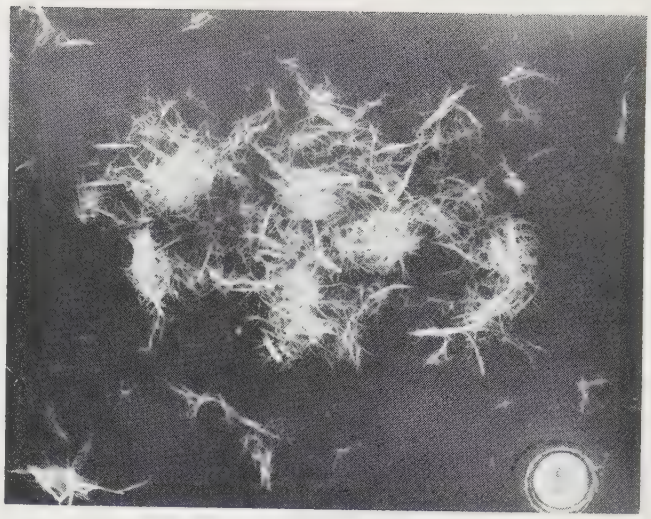

*Fig. 5*

give a positive flow of stock to the plate. This arrangement operated approximately a week when the experimental wiper broke and it was necessary to return to original equipment while we repaired and reinforced the wiper blade. After the wiper and propeller were installed, we ran a tonnage test and were able to produce approximately 400 tons per day of NSSC pulp.

On November 10, the experimental wiper failed again and IMPCO shipped us a new heat-treated stainless steel wiper which was installed and the fibrilizer put back in operation. While still at the high speed, we had several shutdowns when it was necessary to repair the stainless steel stock lines from the fibrilizer to the refiners. We felt that the trouble was due to a high frequency vibration caused by the speed of the fibilizer plate. We changed the sheave on the motor and reduced the speed of the fibrilizer from 550 to 480 r.p.m. No new failures have occurred which have been attributed to the present design speed. Reducing the revolutions per minute of the fibrilizer reduced the horsepower approximately 30%, the pressure in the stock header at the refiner from 30 to 15 lb. As would be expected, this also reduced the maximum output, but still produces our required tonnage.

The fibrilizer has now been in production approximately 10 months in its present design. This past summer an integral inlet and base was provided which allowed the complete unit to be ground mounted. A short 16-in. diam. pipeline with shutoff valve connects it to the cone bottom blow tank. The quality of the material delivered by the fibrilizer is such that we are able to maintain more nearly the same setting on primary disk refiners. By having a uniform mass delivered

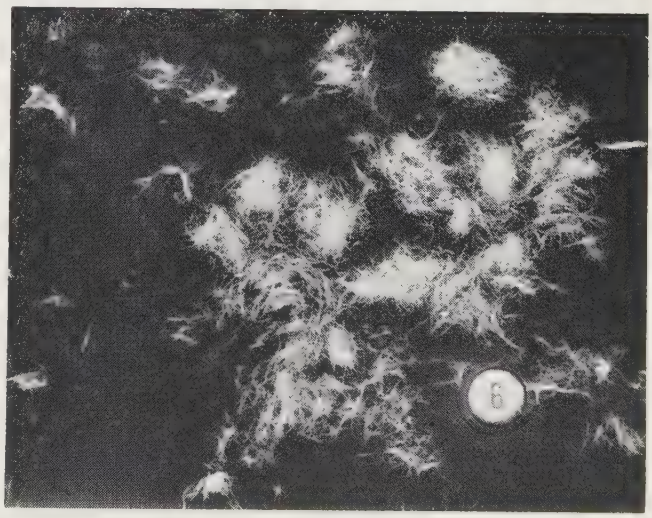

*Fig. 6*

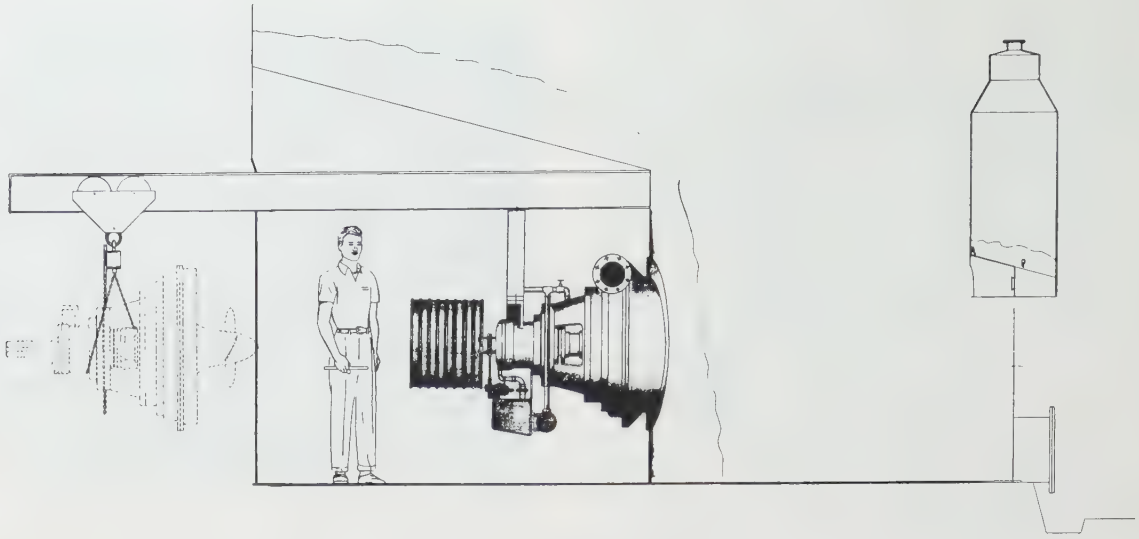

*Fig. 7*

to the refiner, less work is put in at this point for the large oversize particles, and allows the refiners to be set at their optimum point to do their primary function of reducing each fiber bundle to individual fibers.

You noted in Fig. 2, the unit mounted directly on the side of our blow tank, with shaft in the horizontal plane. The adapter does shield the circulation in the attrition zone, but it was found that under certain conditions the agitator could be stopped. The supplier believes that, were this rotor unshielded, Fig. 3, no additional blow tank agitation would be required in the attrition zone. The propeller mounted on the shaft ahead of the plate feeds the high density stock to the unit while the rejected material is returned along the outside of the adapter to the attrition zone of the blow tank.

Visualize, for a moment, a chip moving in the mass as it enters the adapter. The chip or large fiber bundle is moved by the propeller to a point where it is drawn to the surface of the perforated plate. Large bundles are reduced in size and are returned to the attrition zone. Any stock already in individual fiber form or very small bundles, passes through the holes with no further work being done on it. Thus, no concern is given to the amount of stock recirculated from the pressure side of the fibrilizer. This is not true, however, of any close clearance plug or disk refiner.

In our case, we discharge the Solvo pump to a 12-in. header line up to the refiner floor and then back to the low density zone in the base of the blow tank. A manual pressure-regulating valve is used to maintain 10 p.s.i. at the throttling valves of the disk refiners. The stock goes through four primary refiners in parallel and four secondary refiners in parallel followed by washing on vacuum washers. There are no pulp screens in our system.

On startups it formerly was necessary to circulate refined pulp back to the blow tank until such time as the plug refiner could be set up to its normal operating setting after which the primary refiners would be started and a portion of the primary refined stock would be returned also to the blow tank for a considerable length of time until a nest was built up here. This procedure required also continual adjustment of the disk refiners as the system balanced out over a long period. This is no longer necessary as the Solvo fibrilizer delivers, in one pass, uniform pulp that will allow our refiners to go on the line immediately, thus saving considerable start-up time.

Figure 4 shows an enlarged photograph of the typical NSSC pulp as received by the blow tank. Figure 5 shows the degree of pulping obtained by the Solvo fibrilizer, and Fig. 6 shows the finished pulp ready for the paper mill.

Through continuous modification and improvement, we have developed a system which we realize is quite different from the majority of existing neutral sulfite semichemical systems or high yield pulping systems. However, we believe that all of us have sufficiently common problems which will allow you to take with you ideas which will provoke constructive thoughts of your own.

We use vertical digesters and blow to a conventional blow tank. When operating on neutral sulfite semichemical, our operating report shows approximately 12% $Na_2SO_3$ at a 3.7 to 1 liquor to wood ratio for a 5-hr. cook at 60 p.s.i.

We have, on numerous occasions, successfully produced pine kraft through this system at which time we used a long cook to obtain a permanganate number approximately 50. This is with 75 cc. of permanganate. Typical K nos. on three digesters were 49.7, 48.9, and 50.2. When running on high yield pine kraft, our operating report shows approximately 11% active alkali expressed as $Na_2O$ at a 3.4 to 1 liquor to wood ratio for a 5-hr. cook at 60 p.s.i.

Observations made, over one complete year's operation, have provided IMPCO with ideas and data for a new design blow tank. This is shown in Fig. 7. For NSSC the tank would require straight sides. While as yet unproved, it is believed to be a more economical, as well as a space saving design.

Summing up, may I say that we, at North Carolina Pulp were looking for a unit which would simplify our procedures, reduce our horsepower requirements, prepare our pulp for better use of our present disk refiners, and reduce a maintenance problem. It seems to us that all of these conditions have been met.

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# Safety in Mill Electrical Work

M. L. PERKINS

The pulp and paper industry, as a large user of electrical energy, should be very conscious of electrical safety. Electricity, improperly controlled, can cause extensive property damage and personal injury. To establish an effective safety program, we must concentrate on two major areas: (1) system and equipment design, and (2) training and supervision of personnel.

M. L. Perkins, Fraser Paper, Ltd., Madawaska, Me.

## POWER SYSTEM DESIGN

Until recent years, the concepts of interrupting capacity, momentary duty, and short circuit current, were not widely known and as a result not always considered as design parameters for industrial power systems. The amount of short circuit current a system can deliver is just as important in applying equipment as load current. Serious consideration should then be given to present and future loads so that equipment will be purchased with adequate interrupting capacity. When new power sources are to be added to existing systems, they must be connected in so as not to increase short circuit currents beyond the capability of existing circuit interrupting devices.

Equipment grounding is a much neglected area of system design. What data are available indicates that one in four electrical accidents are caused by personnel coming in contact with parts not normally energized. The designer and installer should make certain that a continuous low impedance grounding system extends from power source to every machine.

### *Equipment Design*

One of the main design objectives of the electrical manufacturer should be to make equipment that is safe to install, operate, and maintain.

Some of the elements of good equipment design are:

1. All equipment should be metal enclosed to, (a) provide a barrier against accidental contact with live parts. The addition of mechanical and electrical interlocks to metal enclosures further insures that personnel will not come in contact with energized components, and (b) isolate flashes or fires caused by component failures.

2. Electrical equipment should be interlocked simply but effectively to prevent making or breaking live circuits with devices not intended for this purpose. I am sure we have all said to ourselves at one time or another, "why did he do that, what was he thinking of?" Effective interlocking can help to eliminate this type of accident. In our company, we have had several instances of personnel opening interlocked disconnect switches under load with resulting extensive damage, fortunately only to the equipment. In one instance, a tour electrician was stopping a synchronous motor. After pressing the stop button, he noticed the a.c. ammeter still indicated that the motor was taking full load, so, rushing out he saw flames coming out of the motor. Not knowing any other method, he pulled with all his weight on the ganged disconnect switch, the interlocking mechanism being of light construction, gave way. The resulting explosion seriously damaged two starters and several sections of bus. With a few mechanical modifications, the equipment was beefed up to prevent this from happening again. It does point out, however, that the designer must always keep in mind that he is trying to prevent someone from performing a thoughtless act.

3. Equipment should be easy to isolate from the power source. Drawout, stab-type, or plug-in components, which can be removed and replaced with spare units, to permit servicing, can considerably reduce the hazard of working on or near hot equipment.

Components should be kept to a minimum and readily accessible for maintenance. Adjustments, as much as possible, should be accessible and easy to perform and isolated from high voltage components. Maintenance or adjustments that require difficult or special techniques or tools should be avoided.

## TRAINING AND SUPERVISION

An effective safety program requires a good training program which not only instructs an employee on how to do a job but also how to perform it safely.

A safety manual should be compiled listing key procedures. Do not attempt to cover all circumstances and details for they will never be remembered anyway. It is important that the manual be kept up to date for obsolete rules and procedures will weaken the whole program. You have probably all heard of subliminal advertising on television. The dictionary defines subliminal as: "In the mind without knowing it." This method can be used quite effectively in safety training. Let us take a few examples from our training manual. A rule might go like this. Carbon tetrachloride may be used on all classes of electrical fires. Caution should be used, when in confined spaces, for carbon tetrachloride generates a highly poisonous gas when it comes in contact with heat. Beware of the unexpected. The key sentence here is "Beware of the unexpected" for it applies to all situations and not just some particular one. Another example could be: Rubber gloves should be checked for holes each time before using, by inflating with air. They are to have a high pot test every six months. Never assume when you can be sure. The key sentence here of course, is, "Never assume when you can be sure."

Four or five of these basic or key points can be made into slogans and applied over and over in the manual, in training courses and correlated with actual situations until they become an integral part of the employees' thinking.

There are probably as many lock-out or tagging procedures as there are companies. We have used the following procedure, which we have found very effective. It is based on the premise that an electrician is the person best qualified to isolate electrically driven or controlled equipment so that it is safe to work on.

When an employee desires to have electrically driven or controlled equipment isolated to permit repairs, adjustments, inspections, etc., he shall contact an electrician. The electrician shall isolate the equipment, then take the employee's signed and dated tag, sign his own name opposite the line entitled "Tagged By" and place the tag securely on the switch, breaker, etc., that has been opened to isolate the equipment. From that point on, the electrician's only responsibility is that the tag was placed in such a location to render the equipment safe to work on.

The employee who requested the equipment be isolated is responsible for removing the tag when his work is completed.

When more than one employee is working on the same piece of equipment, the above procedure must be repeated. Never remove someone else's safety tag. If an employee neglects to remove his tag, report the situation to your supervisor.

Any safety tagging procedure requires constant supervision and enforcement. It must be recognized by all employees that violators will be severely disciplined.

New employees should be given intensive training and should be impressed from their first day at work that the safe way is the only way.

Special training courses should be conducted to demonstrate and explain new equipment, how it functions, how it is constructed, what hazards may be present. Ask for comments on the design and safety features. If time allows, dismantle and re-assemble. This type of session will often illustrate many weaknesses which can be eliminated before the equipment is finally installed. A wise man once said "Familiarity breeds contempt" but he should have added "Unfamiliarity breeds disaster."

Supervisors and foremen are the focal point of any safety program. These men, who from their close contact with the employee and to whom the employee looks for direction, instruction, encouragement, and if necessary, enforcement, must understand basic accident prevention and be convinced that good safety performance is a definite requisite of good supervision.

Finally, the supervisor or foreman must be certain that each workman in his charge understands the hazards of the job and how to avoid them. Do not just hand the safety manual to one of your men and say, "Here is the Safety Manual, follow the rules and you will not have any accidents."

The Safety Manual is of no value if it is not gone over rule-by-rule with each worker. He must be shown how to do his job safely and he must be told why it is the safe way. It is obvious, however, that the supervisor cannot anticipate every situation so the worker himself must be trained to evaluate each new situation in terms of safety. Each employee must be made to realize that his attitude toward safety and the company's safety program determines for the most part his own safety.

### CONCLUSION

In conclusion, to achieve good safety performance, management must provide well designed systems composed of high quality components. Electrical manufacturers must be able to offer safe equipment that is economically practical. Management and supervision must be sincere in their promotion and administration of the safety program. Lastly, the employees must be made to realize that the only way to work is to work safely.

# Reduction of Emissions from a Recovery Boiler

**M. W. FIRST, H. E. FRIEDRICH, and R. P. WARREN**

Community concern over better air pollution control and changing technology in the paper industry have stimulated greater interest in control of flue gas emissions from pulp mill chemical recovery furnaces. This paper describes recent pilot studies conducted at large paper mills, and reviews the performance of full scale installations having gas handling capacities up to 160,000 cu. ft. per min.

### CHEMICAL RECOVERY FURNACE OPERATIONS

A number of chemical methods of converting wood chips to paper pulp are dependent for financial success upon recovery of chemicals from the spent digestion liquor, which contains approximately one-half the weight of the original wood in the form of soluble wood products, plus almost all the original pulping chemicals. After concentration in multiple-effect evaporators, or other similar means, the spent liquor is sprayed into a liquid-fuel-burning furnace designed to recover chemicals and produce steam. The dissolved wood products are the source of fuel. Some of the dehydrated and reduced pulping chemicals drop to the bottom of the furnace, but just as in more conventional fuel-burning boilers, much of the smelt escapes with the flue gases and dust collection equipment is required. Usual practice is to pass the combustion gases through an electrostatic precipitator where approximately 90% of the chemicals contained in the flue gases are removed before discharge to the atmosphere. Chemical loadings entering the electrostatic precipitators are high (3–6 grains per cu. ft.) and the precipitator collection plates often become overloaded, reducing the electrical potential and increasing conveying velocities in the narrowed air passages. As a consequence, overall collection efficiency is reduced. Of greater significance from the standpoint of air pollution is "blow-off" from the collector plates of large fluffy flakes of agglomerated smelt particles known as "snow" which settle to the ground in the vicinity of the mill and often cause extensive property damage. Even in areas where air pollution is not an important consideration, the value of the lost chemicals may be sufficient to justify supplementary collection devices.

### MEAD CORP. SODA PROCESS PLANT AT KINGSPORT, TENN.

The nature of the air pollution problem from recovery furnace operations and an outline of suitable remedial steps can be illustrated by the experiences of the Mead Corp. They use the soda process for preparing their pulp and burn the concentrated soda black liquor in a heat and chemical recovery furnace to produce a hot, dry smelt; largely of soda ash (anhydrous sodium carbonate). The combustion gases pass through a heat exchanger where they are cooled and then pass through a Koppers plate-type electrostatic precipitator in which chemical recovery averages 90%. Formerly, the remaining 10% was deposited over the nearby business district of Kingsport in the form of "snow flakes" ranging in size up to one-half inch.

Installation of another electrostatic precipitator, either in series or in parallel, was rejected because the anticipated overall efficiency of 95 to 98% did not guarantee complete elimination of the soda ash snow. A Venturi scrubber, either along or following the electrostatic precipitator was ruled out because of the extremely high draft loss (up to 35 in. W.G.). A Buffalo Forge Co. Type TE Washer received favorable consideration because of its very low draft loss and the ease of solution of soda ash in warm water.

*A pilot model Buffalo Forge Co. TE Washer* having a rated capacity of 1400 cu. ft. per min. and air flow resistance of 0.75 in. W.G. was installed to operate on recovery furnace exhaust gases removed from the breeching following the electrostatic precipitator. The pilot unit (Fig. 1) contained an upstream bank of co-current spray nozzles and flooded scrubber plates followed by two banks of counter-current spray nozzles and flooded eliminator plates. Recirculated water was used for all main sprays and for the first two sets of plate-flooding nozzles. Fresh makeup water was used for the last bank of flooding nozzles. Figure 2 shows the pilot Buffalo TE Washer undergoing tests at the Mead Corp. plant.

Table I summarizes the results of efficiency tests (which covered a period of several months) at gas flow rates ranging from 60 to 125% of rated capacity. Because of the $CO_2$ content of the combustion gases, soda ash was recovered in

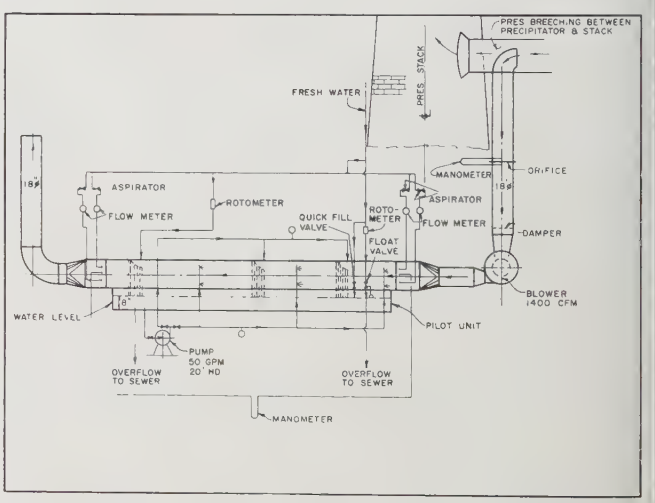


***Fig. 1. Typical TE Washer test set-up for recovery boiler***

solution as sodium carbonate at a strength of 2.4 g.p.l. This solution was re-usable as wash water in the mud washer of the continuous causticizing system and soda ash was recovered from the bicarbonate. The small quantity of material discharged to the atmosphere was in the form of small particles of soda ash and tiny droplets of sodium bicarbonate which showed no tendency to re-deposit.

### FULL SCALE TE WASHER AT MEAD CORP.

On the basis of successful pilot studies, Mead Corp. pur-

M. W. First, Consulting and Research Engineer, Newton Highlands, Mass.; H. E. Friedrich, Mgr., Air Cleaning Div., B. F. Co., and R. P. Warren, Buffalo Forge Co., Buffalo, N. Y.

**Table I. Performance of Buffalo TE Washer Pilot Unit**

| Gas flow, % of rated capacity | 61 | 80 | 91 | 101 | 110 | 116 | 125 |
|---|---|---|---|---|---|---|---|
| Dust loading, grains/std. cu. ft. | | | | | | | |
| Inlet | 0.338 | 0.336 | 0.347 | 0.321 | 0.334 | 0.303 | 0.314 |
| Outlet | 0.028 | 0.037 | 0.037 | 0.041 | 0.034 | 0.041 | 0.057 |
| Efficiency, % | 91.9 | 88.5 | 89.2 | 87.2 | 88.7 | 86.6 | 82.2 |
| Gas Temperature, °F. | | | | | | | |
| Inlet: | | | | | | | |
| Dry-bulb | 216 | 232 | 236 | 238 | 242 | 237 | 246 |
| Wet-bulb | 154 | 162 | 156 | 158 | 158 | 160 | 160 |
| Outlet: | | | | | | | |
| Dry-bulb | 144 | 152 | 149 | 151 | 153 | 156 | 154 |
| Wet-bulb | 139 | 147 | 145 | 148 | 150 | 149 | 150 |
| Pressure drop across scrubber, in. W.G. | 0.35 | 0.49 | 0.63 | 0.75 | 0.85 | 0.91 | 1.02 |

chased a full scale 65,000 cu. ft. per min. capacity unit for installation downstream of the electrostatic precipitators. Rapid corrosion in the black iron pilot unit, due to elevated heat and humidity conditions, plus high concentrations of carbon dioxide, was overcome in the full scale unit by using Type 304 stainless steel construction throughout. Figure 3 shows the full scale Buffalo TE washer in place between the electrostatic precipitator and the stack.

Table II summarizes operating data on the full scale unit. It may be noted that full scale results agree closely with those of the pilot study, but, more important, the discharge of "snow" from the stack was completely eliminated. All that remained that was visible was a faint white fog; largely water vapor condensed from the warm, nearly saturated effluent gases.

*Fractional Size Efficiency Data.* There were collected also, since they make it possible to predict the collection efficiency of a TE Washer when applied to mills using different types of furnaces and primary collectors. Figure 4 shows the "particle size efficiency" curve of the Buffalo Forge Co. Type TE Washer at Kingsport. The TE Washer does not recover material which the electrostatic precipitator preceding it is incapable of collecting; rather, it captures agglomerated salt particles blown off the precipitator plates when they become overloaded or during periods of temporary current interruption.

*Operating Experience at Mead Corp.* Indications were that

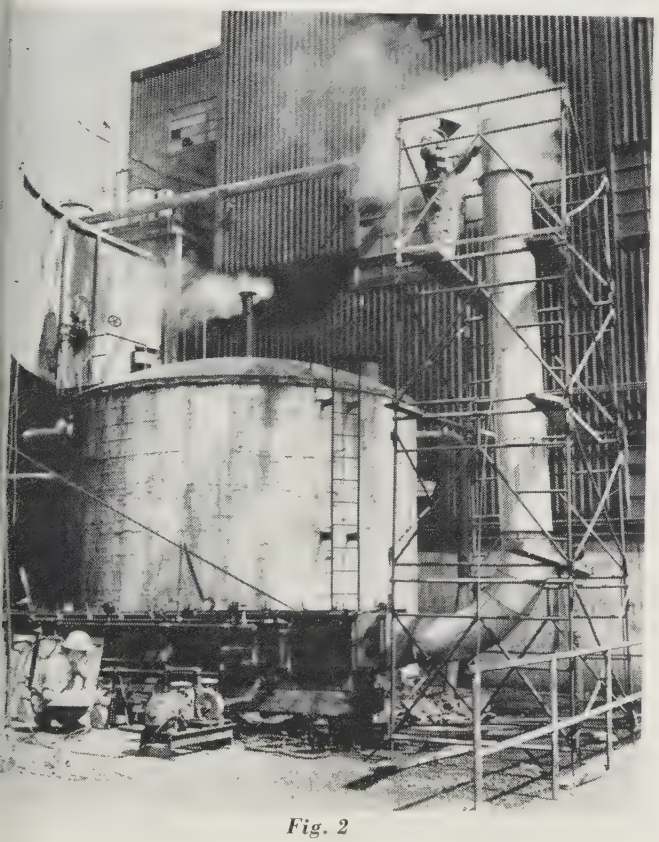

*Fig. 2*

plugging of nozzles with calcium carbonate scale could be eliminated by the addition of small amounts of Calgon to the spray water. At times, crystalline sodium bicarbonate was found on the last bank of scrubber plates, but this was controlled by using hot makeup water instead of cold, at this point. It was found also that the TE Washer could not be operated for more than one-half hour when the electrostatic precipitator was out of operation without risking serious plugging of the first bank of scrubber plates from accumulated salt. However, even when the precipitator was down and the scrubber was taking the full load, it was reported that there was no noticeable increase in the solids discharged from the stack.

## WEYERHAEUSER TIMBER CO. KRAFT PROCESS PLANT AT EVERETT, WASH.

The Weyerhaeuser Timber Co. had an air pollution problem similar to that at the Mead Corp. at their kraft mill in Everett, Wash. They also used a small Buffalo Type TE Washer (shown in Fig. 1) to make pilot scale tests of chemical recovery from the flue gases leaving their Cottrell electrostatic precipitator. Their experimental arrangements are shown schematically in Fig. 1.

In the kraft process of pulp manufacture, salt cake (crude sodium sulfate) is recovered by burning the black liquor, as described above, but otherwise the process is quite similar to that for recovery of soda ash. Results obtained at Weyerhaeuser Timber Co. paralleled those at Kingsport; i.e., efficiency ranged up to 95% depending upon furnace operation. For example, scrubber efficiency was approximately 90% when the fresh water makeup rate was 3.25 gal. per 1000 cu. ft. of gas treated and when gas inlet temperature was greater than 240°F.

Tests at the Weyerhaeuser plant showed conclusively that dust collection efficiency decreased when the flue gas entered the Buffalo TE Washer saturated with water vapor (at the dew point temperature). It seems clear that when the flue gases enter the TE Washer at a temperature considerably above the dew point large quantities of steam or fog are produced at the first bank of spray nozzles; where the incoming gas is cooled below the dew point. Solid particles carried in the gas act as condensation nuclei for the saturated

**Table II. Average Performance Data for Full-Scale TE Washer**

| Gas flow, cu.ft./min. | 57,000 |
|---|---|
| Dust loading, grains/std. cu. ft. | |
| Inlet | 0.21 |
| Outlet | 0.027 |
| Efficiency, % | 88 |
| Soda ash recovered, lb./min. | 1.7 |
| Liquid effluent from scrubber g.p.m. | 25.3 |
| Concentration, g./l. as $NaHCO_3$ | 7.73 |
| Gas Temperature, °F. | |
| Inlet: | |
| Dry-bulb | 272 |
| Wet-bulb | 169 |
| Outlet: | |
| Dry-bulb | 166 |
| Wet-bulb | 162 |

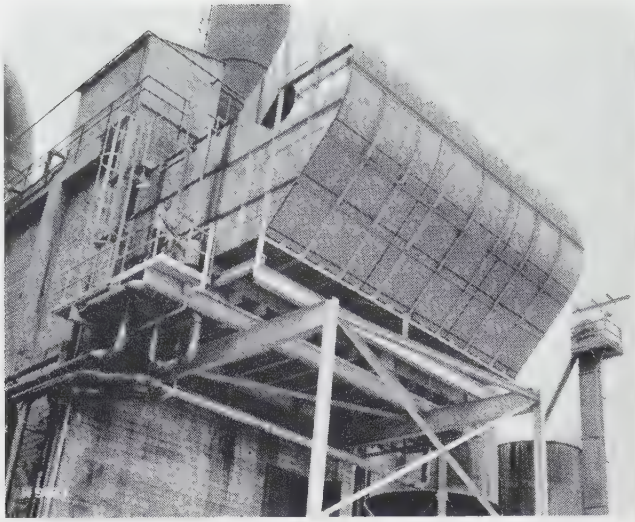

*Fig. 3*

steam and the combination of solid dust particles and water is much more easily captured by the impingement type eliminator plates than either alone. When the gases enter the TE Washer at the dew point, there is little or no fogging and, consequently, little or no particle conditioning in the first stage. This appears to be a satisfactory explanation for the high collection efficiencies shown in the particle size efficiency curve of the full scale TE Washer installed at Mead Corp., Fig. 4, especially in the 5- to 30-$\mu$ size range.

## FIBREBOARD PAPER PRODUCTS KRAFT PLANT AT SAN JOAQUIN, CALIF.

On the basis of successful pilot and full-scale operations at Mead Corp., Fibreboard Paper Products installed a Buffalo Type TE Washer downstream of the Western Precipitator Corp. electrostatic precipitators on their black liquor recovery furnaces. The TE Washer was constructed of Type 316 stainless steel with Monel piping and nozzles and had a rated capacity of 160,000 cu. ft. per min. at 270 to 290°F. and a gas flow resistance not to exceed 1.25 in. W.G. Dust loadings to the TE Washer normally ranged between 0.05 and 0.15 grains per cubic foot, but could rise to greater than 3 grains per cubic foot when the electrostatic precipitators were down. This installation was required because deposits of soda ash from the recovery furnace stacks were creating a nuisance in the vicinity of the plant even though the solids content in the stack effluent was usually well below levels covered by air pollution control codes. Operating personnel at Fibreboard Paper Products stated that the TE Washer met the guarantee to remove 88.5% by weight of dust discharged from the electrostatic precipitators, and to pass no more than 0.05 grains per cubic foot of moisture in the form of droplets 100 $\mu$ in size and greater.

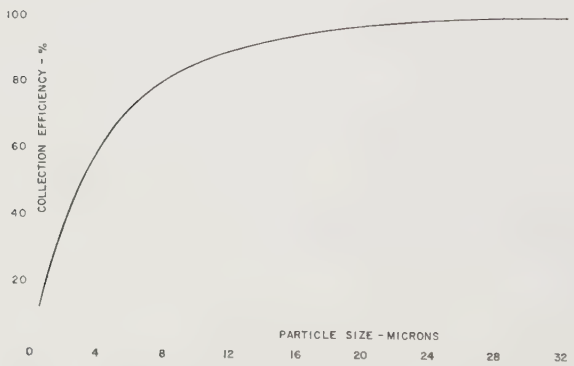


***Fig. 4. Particle size-efficiency curve TE washer-black liquor recovery furnace***

*Fig. 5*

## GENERAL

### *Corrosion Control*

Corrosion control is an important design factor when dea ing with recovery furnace smelts. In addition to the prin pal recovered salts (sodium carbonate, bicarbonate, sulfat which are themselves corrosive to many metals, the furna gases contain high concentration of $CO_2$ plus sulfur gas such as $SO_2$ or $H_2S$. The temperature characteristics plastic coatings and linings (e.g., polyvinyl chloride, phenoli or polyesters) generally rule them out of consideration f furnace gas applications, even when precooling is feasib since in practice breakdowns of the gas cooling apparat cannot be eliminated entirely. It was found possible operate an organic resin-coated steel pilot washer over sever months without excessive corrosion, but only at the cost what amounted to almost weekly renewals of the interi coatings (which required considerable maintenance ti even for a 1400-cu. ft. per min. unit). Therefore, stainl steel (Type 304 and 316), which has good heat characteristi and possess excellent corrosion resistance for all comm chemicals except chlorides (largely absent in pulp m recovery furnace operations), has been used in full-sc units. The greater initial cost is thought to be more th compensated by low maintenance requirements over the l of the unit. The TE Washer at Mead Corp. has now be in service over 4 years, and when inspected during annu maintenance shutdowns, there has been no evidence of si nificant chemical attack. The Fibreboard unit in operati approximately 2 years has required some replacement d to the use of some type 304 stainless steel construction in t unit. In this installation Type 316 stainless steel seems be the best answer, while at the Mead Corp. Type 304 stai less steel was suitable.

A full scale TE Washer contains three sets of sprays a flooded zig-zag plates. The first two sets of bent plates a scrubber units (without eliminator lips) and the third, stan ard eliminators. Each bank of spray nozzles may be point to spray concurrently with air flow or counter-current and fresh water or recirculated spray liquor may be used plate and/or flooding sprays. Counter-current sprayi produces somewhat higher air flow resistance, but is genera more effective for the removal of small particles. Floodi the final bank of eliminator plates with fresh water is favor to minimize passage of droplets of the recirculated chemic solution.

### *Air Flow Resistance*

Resistance to air flow of the TE Washer is 0.5 in. W.G.

ated capacity of 500 cu. ft. per min. per sq. ft. of face area or co-current spraying. Counter-current spraying raises air flow resistance to 0.75 to 1.0 in. W.G. at rated capacity. Spray nozzles operate at 25 p.s.i. and the three banks supply approximately 14 gal. of water per 1000 cu. ft. per min. of gas treated. Flooding nozzles operate at 5 p.s.i. and supply a total of $3^1/_2$ gal. per 1000 cu. ft. per min. to the three banks of bent plates.

*Recirculation*

Spray water recirculation may proceed until the chemical content reaches a concentration where "salting-out" on the bent plates begins. If continued beyond this point, the unit becomes rapidly plugged by bridging of the narrow channels inside the banks of bent plates. If plugging should occur accidentally, it may be corrected rapidly by shutting down the recirculating liquid pumps and substituting hot, fresh water until the accumulated salt encrustations are dissolved. Salting-out can be prevented by (1) continuously bleeding a small amount of fresh water into the unit, usually on the final bank of bent plates (eliminators), and drawing off an equivalent amount of chemical solution through an overflow weir, or (2) by flushing the entire unit with fresh water on a periodic time cycle.

The maximum chemical concentration that can be built up in the washer will depend on the solubility characteristics of the particular salts that are recovered and, the temperature of the entering gases and the spray water. For example, the TE Washer at Mead Corp. was adjusted to give a liquid effluent containing 7.7 g. of salt per liter of solution.

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# The Organization and Operation of an Instrument Department in a Paper Mill

JAMES K. POWELL

During the years since World War II, most of us have become familiar with the word "automation." When first coined, the accepted definition of automation was such that it embraced all types of instruments and controls. Lately, the meaning has changed somewhat, and generally speaking, automation is now considered to mean only certain types of automatic industrial operations. An example of automation in a paper mill would be the automatic conveying systems in the finishing and shipping department.

Another work with which most of us are more or less familiar is the word "instrumentation." This word has come to have a rather broad and complex meaning. D. M. Considine, in his introduction to the "Process Instruments and Controls Handbook," published by the McGraw-Hill Book Co., defines instrumentation as the art of applying measuring devices to a process, or a portion of a process, to determine the magnitude of a variable, and in some cases, to control the value of the variable within certain limits.

This definition of instrumentation can probably be clarified somewhat if we consider briefly what type of equipment is covered by the word instrumentation. Briefly, the equipment covered is: all indicators, recorders, controllers, and any combination of these three, whether the measuring systems be pneumatic, hydraulic, electric or electronic; all final control elements such as control valves, cylinders, etc.; all lines connecting the recording, indicating, or controlling equipment with the final control elements; all transmitters and such primary measuring elements as orifice plates, flow nozzles, etc.; all supports for transmission lines and receiving equipment.

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In this paper we will be concerned with the type of equipment which, according to the preceding definitions, would be classified as instrumentation.

## HISTORY

The history of instrumentation, as we know it today, is relatively young. Most of the instrumentation used today by industries of all types has been developed during the past 25 years. This development has been necessarily slow, the instrument manufacturers being guided in their work by suggestions and criticisms from the users.

The pulp and paper industry has been particularly slow in taking full advantage of the available instrumentation, with the greatest advances in the use of instrumentation having been made in the industry during the last 10 years. During this 10-year period the rapid increase in the production of the pulp and paper industry has made instrumentation a necessity in order to maintain paper quality and paper machine efficiency. With the rapid increase in production, pulp and paper mills have found instrumentation to be an invaluable aid. Today, in almost all pulp and paper mills, instrumentation is recognized as a necessary aid in maintaining the production standards dictated by a highly competitive market.

The recognition of the need for instrumentation has brought about the development of a group within the paper mill organizational setup whose sole function is to maintain this instrumentation in an operating condition. The development of this group has resulted in the recognition of a new maintenance craftsman in the industry, the instrument mechanic. This new craft has gained considerable status within the last 10 years in the industry and the instrument mechanic has begun to be accepted as a specialized craftsman along with the electrician, pipefitter, and millwright.

Today in most of the older mills, the group responsible for maintaining the instrumentation can be likened to the fictional Topsy—it was not born—it just grew. These mills normally started with a bare minimum of instrumentation, consisting primarily of pressure gages, temperature indicators, and a few flow meters and level gages. As the number of instruments increased, it eventually became necessary to assign someone the job of maintaining the instruments. As the amount of instrumentation continued to increase, the size of the instrument maintenance group increased also, until the group became large enough to be classified separately. Although a specialized type of work is done by instrument personnel, the group is usually attached to a maintenance department, or in some cases, to an operating department.

In contrast, most of the paper mills which have been built within the last 10 years have usually begun operation with a group specialized in the care of instrumentation already organized to do this work. In most instances, however, the personnel in charge of instrumentation are still a part of some other department.

The purpose of this paper is to describe the organization, growth, and present operation of an instrument group in a relatively new mill, where the group has been given separate departmental status.

## ORGANIZATION

The organization of an instrument department for a new mill is of necessity a "tailor-made" job. The quantity and quality of personnel required and the specific skills desired are dependent upon many factors. Listed here, in question form, are what we feel to be some of the principal factors upon which an instrument department should be organized:

1. What types of work are to be done by the department? Will maintenance work alone be done, or will the selection and installation also be the work of the department?
2. Will any necessary engineering work be done by the department?
3. Since maintenance work can be roughly divided into two

major classifications—(a) preventive maintenance and (b) breakdown maintenance—how much of each kind of maintenance will the department be expected to do?

4. Will the instrument group be a separate department, or a section of another department?
5. Will the department have trained specialists who will only work on special equipment, or will all workers be expected to service all equipment?
6. What equipment will be serviced by the department? Will clocks, vending machines, etc., be maintained by the department?
7. Will purely electrical instruments, such as voltmeters and ammeters, be serviced by the department?
8. Will maintenance records be kept on equipment serviced?

The organizational factors covered by these questions may not be complete, but it is felt that the more important factors have been listed. It is upon these factors that the organization and growth of the instrument department to be discussed here are founded

The instrument department was organized with the intention that the department personnel would be responsible for the instrumentation in all operating departments of the mill. They would be responsible for the specification, selection, installation, operation, and maintenance of all instrumentation, and the training of instrument personnel. In addition, the supervisory personnel were to be capable of handling the engineering problems which might arise in any phase of the instrument department activities.

It was also decided that all purely electrical instruments, voltmeters, ammeters, wattmeters, etc., as well as the electrical instrumentation necessary for paper machine speed control, would be under the jurisdiction of the electrical department. The two groups would work closely together, but operate under separate supervision.

From the beginning it was realized that a good preventive maintenance program would (1) reduce the number of breakdowns which might affect production, and (2) appreciably increase the life of the equipment. With this in mind, the department was initially organized, and gradually increased in size, based on a program of preventive maintenance. Enough additional personnel were added to carry on day-to-day repairs and installations.

At the start of mill operations the instrument group was a part of the engineering department. The supervisor in charge was classified as instrument engineer, and answered directly to the chief engineer. Sometime later, changes were made in the mill organizational setup, and the instrument group was given full departmental status. The supervisor in charge was reclassified as instrument superintendent.

The instrument department began operations with an initial work force of four day mechanics and two helpers. Due to the mill expansion and the accompanying increase in work load, the department has grown considerably during the past few years. At present the organizational setup consists of: instrument superintendent, instrument foreman, assistant instrument foreman, four shift mechanics, six day mechanics, and six day helpers.

The instrument superintendent now is responsible directly to the production manager. He attends all general staff meetings and any additional meetings at which questions concerning instrumentation are likely to arise. In this way the instrument superintendent can directly keep abreast of changes or additions which will affect his department. Likewise, it gives top management and the other department superintendents an opportunity to hear directly from the person in charge of instrumentation in case of problems in that field.

### *Specification and Selection*

The specification and selection of the proper instrumentation for a job is primarily the responsibility of the instrument superintendent. It is the responsibility of the instrument superintendent to determine the proper instrumentation for each installation, keeping in mind cost, accuracy, dependability, and durability. If the job is small, requiring no extensive initial cost estimate, and a relatively small amount of engineering, the instrument superintendent handles the job alone, with assistance from other instrument department supervisory personnel. On the other hand, for any major expansion which will involve specifications for a large amount of equipment, engineering and development engineers handle the major portion of the work with the instrument superintendent acting in a consulting capacity.

It might be well to trace the procedure used for adding instrumentation in normal, everyday operations. When new instrumentation is desired for any operating department in the mill, the department superintendent presents the problem to the instrument superintendent, either directly or through the mill engineering department. The instrument superintendent determines the approximate cost of the instrumentation and notifies the operating superintendent. If the operating superintendent feels that the necessity for the instrumentation justifies the cost, he issues a work order requesting that the instrumentation be purchased and installed.

The work order is circulated to all maintenance departments that will be involved in the installation of the instrumentation for a cost estimate. The instrument superintendent enters an estimate of the cost of the instrumentation and an estimate of his department's installation cost. The work order then goes to top management for approval.

If given final approval, the work order is given a job number and a departmental account number. These numbers are used in charging material and labor cost to the job. The instrument superintendent requisitions the required amount of instrumentation; he specifies the type of instrumentation and the manufacturer from whom the instrumentation should be purchased.

### *Installation*

The installation of the instrumentation is either done by mill maintenance personnel or by contractor personnel, depending upon the size of the job. Instrumentation installation standards have been set up and must be followed whichever group does the job. In case contractor personnel are performing the work, the job specifications cover the installation standards.

If the work is done by the instrument department group, the instrument foreman or assistant foreman supervise the installation. If the work is done by contractor personnel, the installation is inspected periodically by instrument department personnel to assure that the installation is correct. The job may be of such magnitude as to warrant a full-time inspector from the instrument department. In this case an instrument mechanic is set up to the job of instrument inspector and given the task of watching over the installation.

After the instrumentation has been installed, a thorough check is made on the complete installation by instrument department personnel to make sure that everything is in proper operating condition. All pneumatic lines are checked for continuity and leaks; all control valves are stroked and the valve positioner calibrated; all recorders, indicators, and transmitters are checked for proper calibration; all control systems are aligned. When the instrumentation is released to the operating department it is ready for their use.

During the checkout each piece of equipment is given an identification number, and a stainless steel tag carrying this number is attached to the equipment. This number is used to aid in identifying the equipment for maintenance record purposes.

### *Maintenance*

As indicated in the organizational setup, there is one instrument mechanic on each shift. The shift mechanic's primary duty is to take care of breakdowns. In addition, he is re

quired to do a number of routine inspections. A log sheet is provided so that he can check off each item as it is inspected. A log book is also provided for the shift mechanics in which all the service calls are recorded. He records the time, the nature of the trouble, the location, and what was done to correct the trouble. This permits the supervisory personnel to keep up with the troubles encountered on the two night shifts. If a breakdown occurs on one of the night shifts which will consume too much of the shift mechanic's time, he notifies the instrument foreman. The foreman, upon approval of the operating department tour foreman, then calls another mechanic in to take care of the breakdown

For the purpose of further preventive maintenance, the mill is divided into four work areas. A day mechanic and a helper are assigned to each area. The area mechanic is responsible for the proper operation of all of the instrumentation in his area. The area mechanic is required to do daily, weekly, monthly, and semiannual preventive maintenance, and check sheets are provided for each. The area mechanics are rotated approximately every three months, so that over a period of time each mechanic becomes completely familiar with the entire mill operation, and no mechanic spends an excessive amount of time in one area. A log book is provided for the area mechanic in which all service calls are entered.

A system of equipment file cards has been organized. The cards are split into three groups—one for instruments, one for transmitters, and one for final control elements. Each card contains all the pertinent data about the equipment, and also carries a code number. The code number identifies the equipment as to the operational department location, the variable involved, and lists the identification number. In addition, a service card for each piece of equipment has a space for entering work done on the equipment. When work of a permanent nature is performed, the information about the work is recorded on the service card.

One of the major functions of any instrument shop is the accuracy check or calibration of equipment. A calibration procedure can be a time and labor consuming job unless adequate facilities are available in the instrument shop for the testing of all mill instrumentation. The necessary equipment has been installed in the instrument shop, which makes it possible to check the accuracy of the instrumentation in the mill with a minimum of difficulty. Portable testing equipment is also available for use on that portion of the instrumentation which is difficult to remove to the instrument shop.

All recorder charts in the mill are changed daily by the instrument helpers, with the exception of those electrical instruments which are serviced by the electrical department. The instrument helpers are also required to stamp each recorder chart with a title and date. The chart title gives complete information about the process, such as the application, the variable or variables involved, chart factors, integrator factors, and the identification of each variable by ink color on a multipen recorder. This information is important to the operator and is kept up-to-date when changes are made. Each chart is also given a number which makes it simple to identify any individual chart, and makes it much easier to locate an individual chart in storage. The chart titles and numbers are stamped on the chart by means of a stencil, and the date is added with a rubber stamp dater.

The instrument shop is centrally located on the main operating floor of the mill. There is approximately 1500 sq. ft. of floor space in the main shop. An additional 180 sq. ft. of space is used for recorder chart storage where both unused and used charts are stored. The instrument foreman and assistant foreman share an office which is located just off the instrument shop.

Individual tool lockers are provided for each man. Each mechanic is required to furnish his own small tools, which he can buy at cost through mill stores. All additional tools and equipment are supplied by the mill.

Spare parts for all instrumentation are carried in mill storeroom stock. The instrument department requisitions the initial item and recommends the maximum and minimum amounts which should be carried in stock. The decision as to whether an item should be carried as a spare is dependent upon whether the lack of that item would affect production. The amount of any particular item that is carried as a spare is dependent, of course, on the quantity of equipment using this item. The instrumentation selected for the mill expansion programs during the last few years was affected to some degree by the desire to keep spare parts to a minimum. The use of only two major instrumentation suppliers makes this possible.

Any instrument or control valve which becomes inoperative is removed from service and returned to the instrument shop. The instrument or control valve is checked completely and put in first class condition. The equipment is then placed in storage and reused at the first opportunity. This procedure reduces the inoperative instrumentation to a minimum, and reduces the instrumentation cost of new installations.

***Training***

It became apparent shortly after the mill began operation that in order to maintain the desired preventive maintenance program, plus other required departmental activities, it would be necessary to increase the instrument force. The authority to hire additional personnel was obtained as quickly as the work load indicated the increase was economical. Several additional mechanics were hired from outside the mill until such time as the original helpers had gained sufficient experience to be advanced to the classification of mechanic. Since that time a policy of training and promoting from within the mill has been carried out. As a result of this policy the instrument foreman and assistant foreman were promoted from the mechanic classification, and four of the present mechanics were originally hired as helpers.

In line with the policy of training and promoting from within the mill, helpers are carefully selected from mill personnel in other departments who have requested a transfer to the instrument department. By using written aptitude tests and personal interviews, plus a careful consideration of the applicant's mill-work history, we have been successful in obtaining first class mechanic material. This method has proved so effective we have found it unnecessary to look outside the mill for prospective helpers.

Most of the training has, of course, been for the benefit of the instrument helpers. However, we have taken advantage of the excellent training made available at instrument manufacturer's training schools. These schools offer training to instrument personnel at no cost to the mill, except for living expenses. The two major suppliers of instrumentation to the mill both offer training courses. All of the present instrument mechanics have attended one of these schools, and the instrument foreman has attended both schools.

One further aid in information distribution which is utilized in the use of schematic diagrams and written explanations. A schematic diagram and an explanatory writeup are made on all unusual control systems. A copy is distributed to each person in the department.

Several years ago the company put into operation a means of assisting in the education of mill personnel. The company will pay for approved school courses undertaken and satisfactorily completed, the only prerequisite being that the course must be in a subject which will aid the worker in his occupation. All of the present instrument helpers have either completed or are in the process of taking a correspondence course on instrumentation.

In order that all instrument department personnel may be kept aware of changes or additions, periodic informational meetings are held. At these meetings the instrument foreman and assistant foreman discuss any changes that have taken

place, either in the mill process or in mill instrumentation, and answer my questions which may arise concerning these changes.

One additional phase of training which has not been overlooked, and certainly not minimized, is that of safety training. In conjunction with the general mill safety program, departmental safety meetings are held once a month. All supervisory personnel are involved in this meeting each month and the remainder of the personnel on a rotating basis. In addition, periodic safety meetings are held involving all departmental personnel.

### CONCLUSION

We realize that the instrument department discussed here would not operate satisfactorily in all pulp and paper mills However, we do feel that the basic concepts which we have endeavored to keep in mind while developing this department are necessary in order to have an instrument group which operates efficiently.

As suggested before, an instrument department should be tailored to fit the individual mill. A goal should be set and an ideal toward which to work. This will make it necessary to do the planning which is a prerequisite for any successful maintenance department.

The instrument department we have discussed has been in operation for five years, and has not yet reached the goal which was initially set. We feel that some of the basic questions do not as yet have adequate answers. While we continue to work toward an ideal department, we feel that the instrument department as now operating can efficiently handle the multitude of problems which arise with the mill instrumentation.

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# General Purpose Semiconductor Rectifier Power Supplies in the Paper Industry

G. E. SHAAD

THROUGHOUT the average paper mill are found applications for general purpose d.c. power, regulated or nonregulated, requiring one or more kilowatts of 125 or 250 v. d.c. power. Magnet power supplies, synchronous motor excitation systems (group or individual), constant potential d.c. power bus, and a multitude of other general purpose applications are presently using semiconductor rectifier power supplies. We can expect their use to increase in the future as the industry more fully recognizes their advantages of low installed cost and low maintenance.

In recent years, the art of manufacturing semiconductor rectifiers has moved amazingly rapidly. New concepts, new ratings, new manufacturing techniques, and new economic relationships have piled one upon the other so rapidly as to create considerable confusion on the relationship of the various rectifying devices. While the art is still progressing rapidly, sufficient information is available on efficiency, performance, limitations, etc., to permit a logical review of the various systems as they apply to general purpose applications in the paper industry.

Four semiconductor rectifier devices are in general supply: copper oxide, selenium, germanium, and silicon. They became available to industry in this order and each as it was introduced had definite advantages with respect to the previously available devices.

*Copper Oxide.* Dating back to the 1920's the copper oxide rectifier is inherently a low-voltage rectifier that has its peak efficiency at about 6 v. At one time in very general usage,

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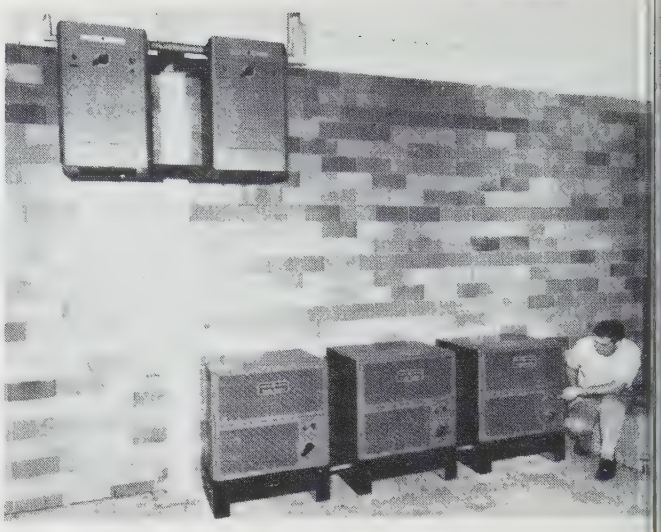

*Fig. 1. 5-kw. and 12½-kw. selenium rectifiers supplying synchronous motor excitation in paper mill*

it has been superseded on general purpose power supply applications because of cost and efficiency.

Copper oxide rectifiers are occasionally used today for low applications (under 1 kw.) where only pulse service is desired and advantage can be taken of the high short time overload characteristics of the copper oxide cells. Copper oxide stacks do not un-form and have very long life. In applications where the rectifier may not be energized for long periods of time but instantaneous output is required when energized copper oxide units may still be considered.

*Selenium.* Available for many years, selenium has continued to be improved in efficiency and voltage capabilities so that today's units are greatly improved in overall characteristics. Selenium is the economical approach to the small

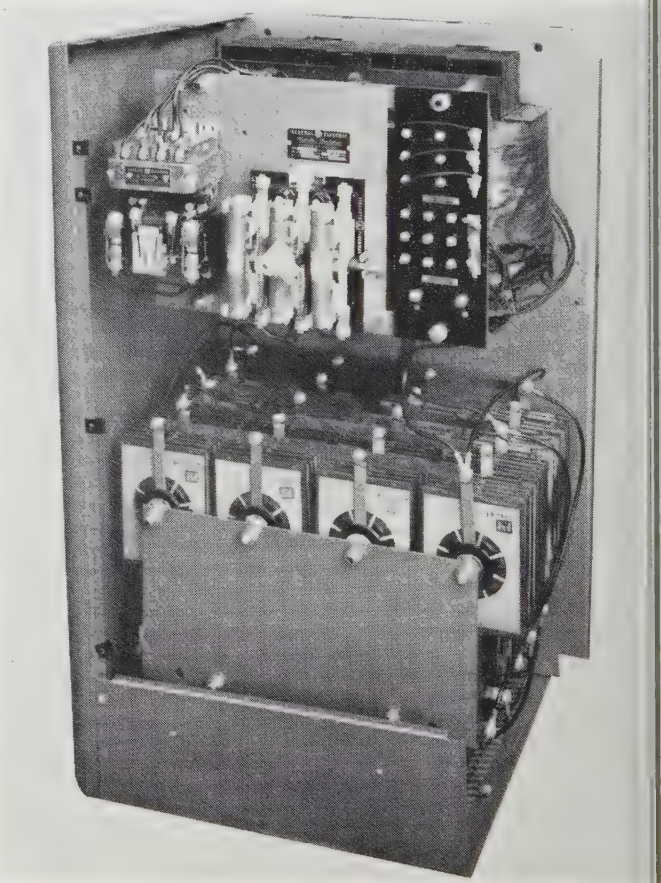

*Fig. 2. Typical construction of convection cooled selenium rectifier*

and medium power supply units since the individual cells are inherently relatively low-current elements. The ability to arrive at the desired total rating by using groups of cells rather than a single oversized cell is advantageous from a cost standpoint.

Like the copper oxide rectifier, selenium with its considerable rectifying area and heat storage capacity can withstand high, momentary peak currents without damage. In addition, selenium can be subjected to excess inverse voltage peaks without total failure. In applications such as synchronous motor field excitation units, this surge voltage withstand capability permits the use of standard units without special precautions.

When first available, selenium cells exhibited an ageing characteristic that resulted in a considerable reduction in d.c. output voltage in a few years of operation. These first cells also tended to unform when de-energized for long periods of time. Today's manufacturing techniques have greatly reduced these tendencies. Aging is no longer a problem and spare selenium stacks can be kept on the shelf for years without becoming significantly unformed.

*Germanium.* The first of the high-power, high-efficiency semiconductor rectifiers was germanium. Commercial units first became available about 1952. By comparison to selenium and copper oxide units, germanium provided a higher blocking voltage, a lower forward drop per cell, and a resultant high overall efficiency. Germanium units still have these advantages, but germanium is inherently a low temperature component and the cooling of high power germanium units is a major problem. For general purpose power applications, germanium has been rather universally superseded by silicon.

*Silicon.* The work with germanium led the way for the laboratory development of the silicon rectifier. Silicon units have been commercially available since 1957 and have demonstrated great advantages in terms of high blocking voltages, high current capacity, high operating temperatures, and high efficiency. The forward voltage drop per cell of today's silicon cells is nearly as low as the voltage drop of germanium cells while the blocking voltage capability is over twice that of germanium.

The high current density existing in the active rectifying area together with limited heat storage capacity limits the overcurrent capabilities of the cells. Properly coordinated short circuit protective devices are essential for cell protection for without well coordinated protection, an overload or a secondary fault could result in complete failure of the rectifying devices. In addition to protection against excessive forward currents, protection against excessive reverse voltages must be provided. Surge voltages in excess of rated cell voltage applied for even microseconds of time may result in cell deterioration or failure. This extreme sensitivity to inverse voltages created a good many operational problems in early installations of germanium and silicon units. It can still create trouble today if adequate consideration is not given to the application and the operating conditions.

These are the general relationships of the various types of rectifying devices available today for general purpose 125- and 250-v. applications in the paper industry. From this it becomes apparent that copper oxide is limited to specialized applications, selenium is commonly applied in the small and medium current classifications (less than 300 amp.) germanium has generally been superseded by silicon, and silicon is the logical choice for the medium and larger current applications.

In the smaller sizes, the economic and application advantages of selenium outweigh its reduced efficiency. In the large units, however, silicon has the advantage of both cost and efficiency.

A typical application of general purpose selenium rectifiers is shown in Fig. 1 where 2- to 5-kw. and 3- to 12½-kw. selenium units are supplying excitation to synchronous motors. Figure 2 shows the internal arrangement of a 5-kw. unit. Figures 3, 4, and 5 show the construction details of a 125 kw., 250 v., air-cooled silicon rectifier typical of units used to supply a general purpose d.c. bus.

The desire of the paper industry for static power supply systems will increase the number of general purpose rectifiers that will be installed. The plant engineer, however, must give consideration to the following fundamentals in selecting the rectifier and planning its location.

*Fig. 3. 125-kw., 250-v., air-cooled silicon rectifier for general industrial service*

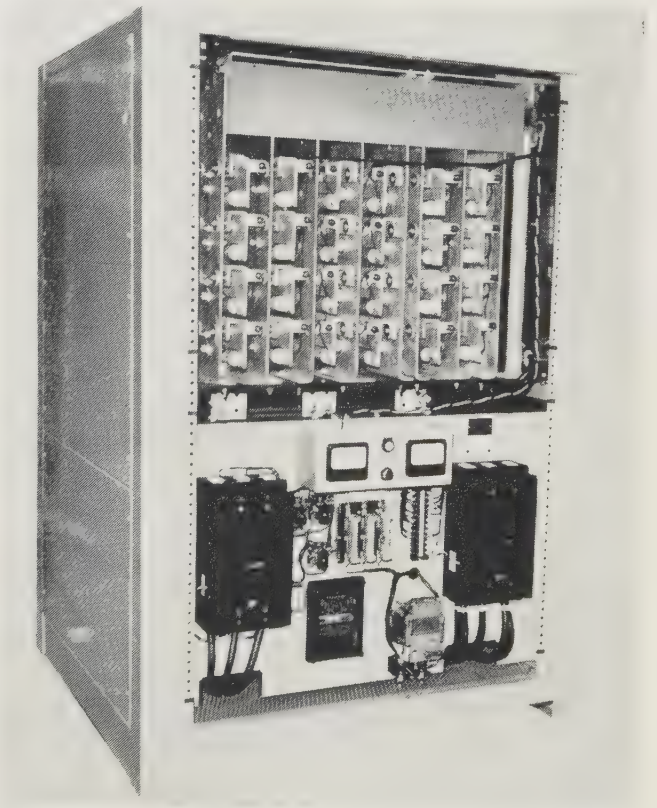

*Fig. 4. Internal construction of air-cooled silicon rectifier for general industrial service*

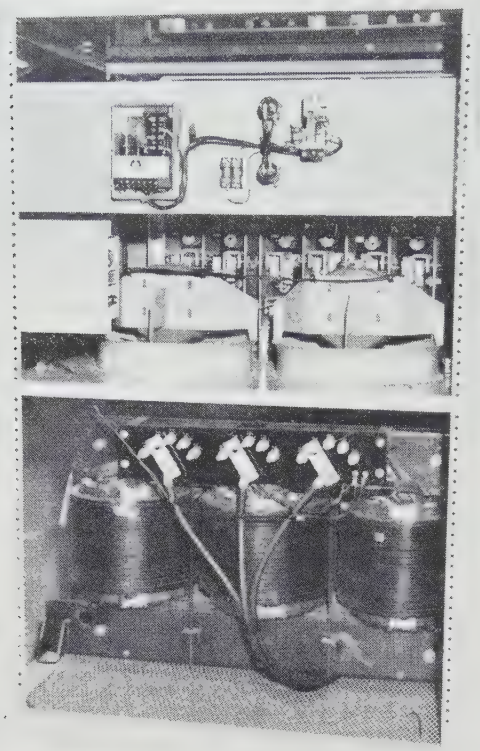

*Fig. 5. Transformer and cooling fans on 125-kw. industrial silicon rectifier*

1. *Voltage sensitivity.* The output voltage from semiconductor rectifier packages is normally not regulated. Changes in a.c. supply voltage will result in a corresponding change in d.c. output voltage. If this change in d.c. voltage will affect the equipment involved, consideration should be given to a saturable reactor or Inductrol regulator for control of the output d.c. voltage.

2. *Voltage adjustment.* The output voltage is normally adjustable only by the changing of transformer taps with the system de-energized. If the d.c. voltage must be adjusted during operation separate means (such as an Inductrol regulator) must be provided.

3. *Ventilation.* Units above about 5 kw. are usually force-ventilated while smaller units are connection cooled. Adverse atmospheric conditions and surrounding environment must be considered. Although individual cells are protected from general conditions (special paints on selenium cells and sealed inert gas filled protection of silicon cells) many parts can be corroded to the point of failure if the installation site is poorly selected. Ambient temperatures above 40°C. (104°F.) max. and above 30°C. (86°F.) average will require evaluation of possible derating of the equipment. Where atmospheric or ambient conditions are a problem, water cooling or air-to-water heat exchanger systems may be required.

4. *Overload protection.* Adequate protection against equipment failure as a result of secondary short circuits or single cell string failure is essential. The need for continuity of service makes it imperative that equipment be so designed and protected that equipment damage will not result from secondary short circuits. Where more than one load is fed from a single rectifier, the protective devices should provide for selective tripping of feeder breakers without loss of power to the other feeders.

5. *Surge voltage protection.* Silicon rectifiers applied to loads (such as synchronous motor fields) that may create high surge voltages require surge-voltage protection limiting the possible inverse voltage applied to any cell to a level well below the cell rating. The use of cells with increased inverse voltage ratings is usually not sufficient. The necessary circuitry to limit the maximum total surge voltage and to insure the even distribution of this voltage across the individual cells should be provided.

6. *Regeneration.* Rectifiers will not accept regeneration unless specific provision is made to absorb pumpback power. Elevators, cranes, etc., often require such a provision. The normal practice is to provide dynamic braking resistors automatically applied to the d.c. bus if the d.c. voltage rises above normal values.

7. *Voltage regulation.* The no-load to full-load regulation will vary from a regulation of 5% to perhaps 15%, depending upon the manufacturer, the size of the unit, and the type of cell. If changes in d.c. bus voltage with a change in load is objectionable a voltage regulating scheme must be furnished. Silicon rectifiers, incidentally, exhibit less regulation than selenium.

8. *Accessibility.* Although primarily static in design, maintenance and inspection will be required. Reasonable accessibility should be provided in the overall equipment design. (The fan motor, for example, in forced-cooled units must be accessible for lubrication.)

9. *Overload capacity.* The exact overload rating depends upon the particular equipment involved and will vary over a rather wide range. For example, a unit supplying a group of independent loads may encounter a considerable period of overload operation while a unit supplying a single synchronous motor field should never be overloaded unless a short circuit occurs. Each application, therefore, must consider the possible overloads, the possible need for operation with one cell string out of service, the possible need for derating because of ambient temperatures, etc. Only the end-user can establish his requirements as to overload conditions.

10. *Parallel operation.* General purpose rectifiers have sufficient inherent regulation for operation in parallel but will not necessarily provide perfect load division. NEMA Standards state that units shall be considered to be in successful parallel operation if the load they carry does not differ by more than $\pm 15\%$ of their proportionate share of rated load when the load on the units is between 50 and 100% of rated.

The present rectifier industry standards are limited in their coverage and many points that may be involved in paper mill applications are not specifically covered. Overload ratings, for example, are specified in NEMA Standards MR1-1953, Part 6 (Direct Current Power Conversion Units—Unregulated) as 100% load continuous followed by 150% load for 1 min. Overloads for a longer duration are not covered. An ambient temperature of 40°C. max. and 30°C. average is specified, and derating factors for higher ambients are not covered. Overload protection, output capabilities with one cell string out of service, etc., are not yet standardized and must therefore be specified in detail by the user.

Specifically included in these NEMA Standards as "Unusual Service Conditions" that should be discussed with the manufacturer are:

1. Exposure to damaging fumes.
2. Exposure to excessive moisture.
3. Exposure to excessive dust.
4. Exposure to abrasive dust.
5. Exposure to steam.
6. Exposure to oil vapor.
7. Exposure to explosive mixtures of dust or gases.
8. Exposure to salt air.
9. Exposure to weather or dripping water.
10. Exposure to abnormal vibration or shock or both.
11. Exposure to unusual transportation or storage conditions.
12. Unbalanced a.c. voltages.
13. Departure of a.c. system voltages from substantially sinusoidal wave form.
14. Mounting in other than usual positions.

It is important, therefore, that the user understand the operating limitations of a given manufacturer's design and give proper consideration to the required operation and installation conditions of his installation.

Looking into the future of semiconductor power supplies, developments now in process will greatly widen the application field for semiconductor rectifier systems. The cost picture continues to change as manufacturing methods and techniques are improved. New devices such as the "silicon controlled rectifier" will eventually affect the design of general purpose power supplies. New ratings and new economic relationships will continue to evolve to the benefit of industry as a whole as the art of semiconductor manufacture and design continues to move rapidly forward.

The economic and operating advantages of semiconductor power supplies are well proved in many applications throughout the paper industry. It is certain that the paper industry will continue to capitalize on the advantages they provide.

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# Recovery of Dissolver Vent Stack Soda Losses

A. A. BERNHARDT and J. S. BUCHANAN

In November, 1955, a new 350-ton recovery unit was started up at our Nekoosa kraft mill. The smelt shatter system was installed utilizing re-circulated green liquor sprayed through nozzles directed downward at the smelt stream. Subsequent trouble with scaling and plugging in the green liquor piping and nozzles led to the abandonment of this portion of the equipment, since the shower header arrangement did not permit simple cleaning.

Steam shatter nozzles had also been installed on the unit, and these alone proved effective in breaking up the smelt stream. The two side-entering dissolving-tank agitators provided adequate green liquor circulation. A quiet dissolving tank has been the result.

However, in the process of determining the best position for the steam shatter nozzles, an unfortunate incident occurred. These nozzles were at one time located under the spouts and directed against the back side of the smelt stream. This scheme was much too effective in breaking up the smelt, since a large quantity of very small particles were produced. These finely divided droplets, containing smelt material, were entrained in the air and vapor sweeping up through the dissolver stack. The situation required immediate correction from both a monetary and "good neighbor" standpoint.

By moving the steam shatter nozzles to a position over the top of the smelt, and directing the steam down at the smelt stream, the problem was largely corrected. The entrained alkali was reduced to a level where air pollution was no longer a problem.

Briefly, chemical losses from the dissolver stack were determined by a pitot tube transverse of the stack, measurement of wet and dry bulb temperature, barometric and stack pressure. From these data are obtained (1) total volume and velocity of gas and (2) approximate moisture content and the meter sampling rate for entrainment determination based on isokinetic sampling. A sample of the gas and vapor in the stack is then drawn through a thimble at the previously determined rate. The water vapor is condensed and the remaining gas measured in a gas meter. Sodium analysis-using a flame photometer, on the residue collected by the thimble, indicates alkali loading in the gas and vapor.

Subsequent tests disclosed alkali losses averaging 4020 lb. per day as $Na_2SO_4$ or 17.1 lb. per ton of pulp produced, having a value of $68.90 per day (see Table I). Consideration of this information prompted a survey of the problem. Had other people encountered losses of this magnitude, and if so, how had they succeeded in reducing them?

Lawson[1] described the heat and chemical recovery system installed on the dissolver vent of the Newcastle, N. B., mill. This was the only published information on the subject that could be found at the time. Private correspondence offered information that a Pennsylvania mill had installed a cyclone type of collector on its dissolver vent, and that a Florida mill had found dissolver vent losses in the neighborhood of 8000 lb. per day.

The Florida mill had succeeded in reducing the 8000 lb. per day to about 2000 lb. per day by cutting a 3-ft. hole in the 5-ft. diam. stack to act as a check draft, and thus reduce the quantity of air and vapor sucked from the dissolver tank. This approach was tried at Nekoosa but without marked success. The Newcastle scheme was considered but discarded because the lower temperature and humidity of our dissolver vent stack effluent made economical heat recovery impossible. As indicated in Table II, the total heat produced in the dissolver exhaust, per ton of pulp, is of the same order of magnitude at Nekoosa and Newcastle; however, the availability of this energy at Nekoosa is much less. Several attempts were made to increase the heat content of the dissolver vent stack effluent by reducing air dilution to the stack. Other operational problems were introduced with these attempts, hence they were abandoned.

Table I. Dissolver Vent Stack Loading

| Test | Total volume, c.f.m. | Moisture, % | Sodium loss as $Na_2SO_4$ lb./day | Sodium loss as $Na_2SO_4$ lb./ton airdry pulp |
|---|---|---|---|---|
| Before Mist Eliminator Installation | | | | |
| A | 16,700 | 33.2 | 4060 | 17.2 |
| B | 19,500 | 37.1 | 4700 | 20.0 |
| C | 20,500 | 33.0 | 3305 | 14.0 |
| After Mist Eliminator Installation (Before Damper Repair) | | | | |
| D | 15,330 | 46.7 | 1048 | 3.9 |
| E | 14,950 | 39.6 | 963 | 3.6 |
| After Mist Eliminator Installation (After Damper Repair) | | | | |
| F | 10,435 | 29.1 | 174 | 0.7 |
| G | 11,480 | 26.5 | 134 | 0.5 |
| H | 12,140 | 51.3 | 121 | 0.5 |
| I | 11,700 | 36.9 | 73 | 0.5 |

Various types of scrubbers were also considered and discarded because (1) their recovery efficiencies were not so high as desired, (2) water would be added to the alkali system at the expense of lime washing efficiency, and (3) return on required investment was not very attractive.

In September, 1957, our attention was directed by a magazine advertisement to the knitted-metal mist eliminator as a possible solution. The Metal Textile Corp. of Roselle, N. J., was approached and they affirmed that a properly installed mist eliminator could be expected to recover 99% of the droplets over 5 $\mu$ in diameter. They also furnished data which permitted us to design the mist eliminator installation.

As the gas and vapor pass through the knitted-metal mist eliminator the entrained liquid droplets impinge on the surface

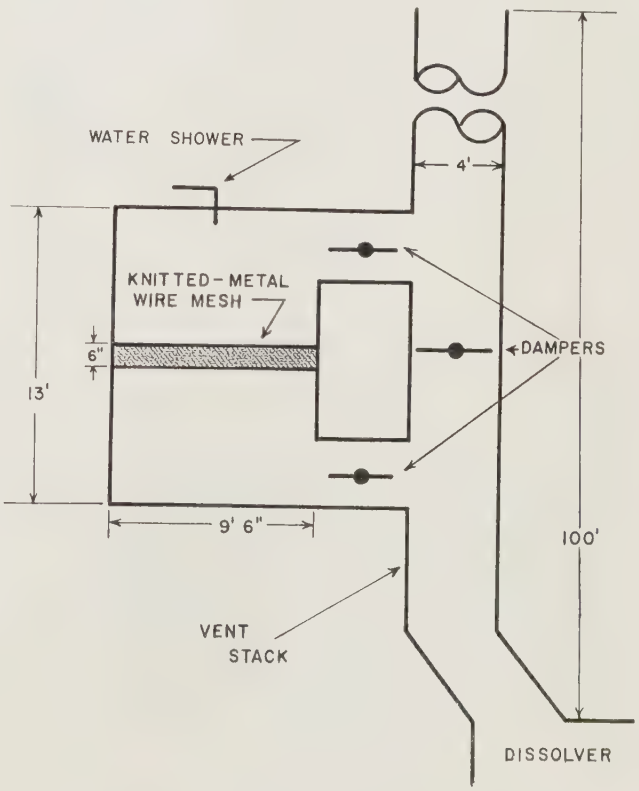


*Fig. 1. Mist eliminator installation*

A. A. Bernhardt and J. S. Buchanan, Nekoosa-Edwards Paper Co., Port Edwards, Wis.

[1] Lawson, G. B., *Pulp & Paper Magazine of Canada*, No. 3: 247–249 (1958) (Conv. issue, 1957).

**Table II. Enthalpy of Dissolver Vent Effluent**

| Test[a] | Total volume, c.f.m. | Temperature, Dry bulb, °F. | Temperature, Wet bulb, °F. | Humidity, lb. $H_2O$/lb. dry air | Dry air, lb./min. | Enthalpy[b], Btu/lb. dry air | Enthalpy[b], Btu/ton air dry pulp |
|---|---|---|---|---|---|---|---|
| | | | Before Mist Eliminator Installation | | | | |
| A | 16,700 | 166 | 155 | 0.310 | 595 | 384 | $1.40 \times 10^6$ |
| B | 19,500 | 167 | 157 | 0.369 | 644 | 451 | $1.77 \times 10^6$ |
| C | 20,500 | 178 | 165 | 0.367 | 705 | 471 | $2.10 \times 10^6$ |
| Av. | 18,900 | | | | | 435 | $1.76 \times 10^6$ |
| | | | After Mist Eliminator Installation (Before Damper Repair) | | | | |
| D | 15,330 | 209 | 169 | 0.571 | 470 | 726 | $1.85 \times 10^6$ |
| E | 15,400 | 176 | 166 | 0.330 | 562 | 431 | $1.31 \times 10^6$ |
| Av. | 15,365 | | | | | 579 | $1.58 \times 10^6$ |
| | | | After Mist Eliminator Installation (After Damper Repair) | | | | |
| F | 10,425 | 211 | 174 | 0.263 | 439 | 372 | $0.91 \times 10^6$ |
| G | 11,480 | 196 | 167 | 0.240 | 493 | 314 | $0.86 \times 10^6$ |
| Av. | 10,903 | | | | | 343 | $0.89 \times 10^6$ |
| H | 12,140 | 205 | 180 | 0.689 | 343 | 832 | $1.55 \times 10^6$ |
| I | 11,700 | 198 | 176 | 0.396 | 436 | 493 | $1.17 \times 10^6$ |
| | 11,920 | | | | | 663 | $1.36 \times 10^6$ |
| Newcastle | | 192 | 190 | 1.096 | 140 | 1298 | $1.37 \times 10^6$ |

[a] Tests A through G during winter; H & I in summer; Newcastle in summer.
[b] Datum = 32°F.

of the wire. There they form into larger drops with sufficient weight to flow downward. When these liquid drops reach the bottom of the mesh, they are large enough to fall back against the rising gas stream into the dissolving tank. The clean gas passes up through the mesh and out the stack.

The most important consideration in design of the installation was the area of the knitted-metal material. This area must be large enough to keep the velocity of air and vapor passing through it below 16.5 ft. per sec. for maximum recovery. A second factor required the draft loss across the mesh be less than 0.1-in. $H_2O$, thereby assuring that ventilation of the dissolver would not be much impeded. Any slight pressure over atmospheric in the dissolver can cause dangerous puffing. The simplest arrangement was to install the mist eliminator directly in the 4-ft. diameter vent stack. Although this design complied with the velocity requirement, the pressure drop across the mesh was much too great. Calculations based on engineering data indicated a tank 7 ft. in diam. would adequately satisfy the velocity and pressure drop requirements. However, an old, cut-up tank, $9\frac{1}{2}$ ft. in diam., was available in our salvage yard. While the tank was larger than the 7-ft. size derived from design calculations, it was available for the cost of re-assembling it. We, therefore, bought the 304 stainless steel, knitted-metal eliminator to fit this tank.

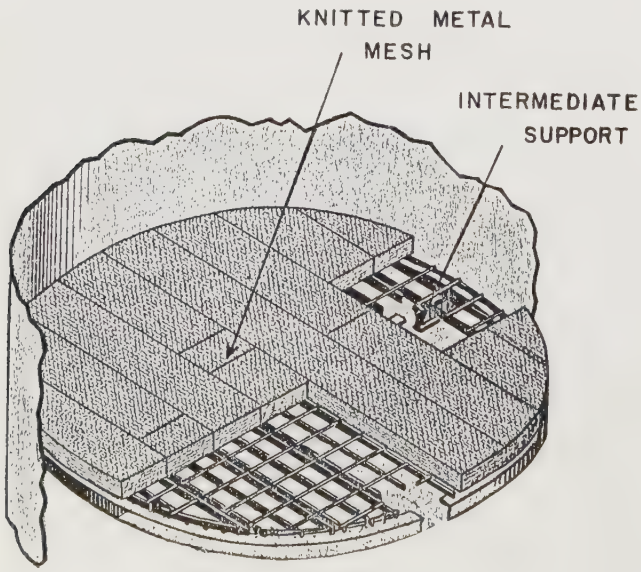


*Fig. 2. Metex mist eliminator—strip type*

The unit was completed and put in service in November, 1958. Complete costs, including installation, was $2600, which was returned in about 6 weeks (see Table III) based on the salt cake savings resulting from reducing the dissolver vent stack loss by 16.3 lb. of salt cake per ton of pulp produced. It was felt that the 3.8 lb. remaining loss was still not entirely satisfactory. This led to an inspection of the installation. It was discovered that the diameter of the by-pass damper was about 2 in. less than the vent stack. This was rebuilt to a much closer fit, and subsequent tests indicated a dissolver vent stack loss approximately 0.5 lb. of $Na_2SO_4$ per ton of pulp.

It was found necessary to wash off the mist eliminator by means of a water shower mounted above it to prevent alkali build-up and the resulting increase in pressure drop across the mesh. Initially, the eliminator was washed every 4 hr. After 8 months of operation, more frequent washings were required, and eventually these did not succeed in maintaining sufficient venting of the dissolver.

The mist eliminator was again examined and found to be seriously plugged with scale deposits. That material on top of the mesh was found by chemical analysis to be 88% calcium carbonate. The material from the underside of the mesh was apparently undissolved smelt. The sections of knitted-metal were removed from the tank and immersed in dilute nitric acid and re-installed.

**Table III. Monetary Value of Sodium**

| Test | Sodium loss as $Na_2SO_4$ lb./ton airdry pulp | Economic value[a], $/day | Economic value[a], $/year[b] |
|---|---|---|---|
| | Before Mist Eliminator Installation | | |
| A | 17.2 | 70.00 | 23,100 |
| B | 20.0 | 81.50 | 26,900 |
| C | 14.0 | 55.20 | 18,200 |
| Av. | 17.1 | 68.90 | 23,700 |
| | After Mist Eliminator Installation (Before Damper Repair) | | |
| D | 3.9 | 18.00 | 5,940 |
| E | 3.6 | 16.60 | 5,480 |
| Av. | 3.8 | 17.30 | 5,710 |
| | After Mist Eliminator Installation (After Damper Repair) | | |
| F | 0.7 | 3.10 | 1,020 |
| G | 0.5 | 2.20 | 725 |
| H | 0.5 | 2.30 | 760 |
| I | 0.5 | 2.30 | 760 |
| Av. | 0.5 | 2.50 | 816 |

[a] Based on delivered $Na_2SO_4$; price = $34.50/ton.
[b] Based on 330 operating days per year.

It is not known whether the calcium carbonate originates from water hardness or smelt carry-over. Therefore, plans are being made to use "combined condensate" water from the vacuum evaporators for the mist eliminator shower instead of fresh water. We thereby hope to prevent a gradual build-up of calcium carbonate scale. Evaporator condensate has proved very effective at Nekoosa, in the green liquor lines, for this same purpose.

We are very satisfied with the mist eliminator installation. It has proved to be a simple and inexpensive means of decreasing chemical losses and reducing air pollution.

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The efforts of V. C. Iverson, Russ Elston, and John Mrochek of our technical department in planning and supervising the data collection are gratefully acknowledged.

# Sulfate Black Liquor Evaporator Operation with Mesh Pad Type Separators

H. D. JURGENSEN, H. E. JACOBY, and H. G. LANKENAU

THE removal of entrained mists from vapor streams has been recognized for many years as a prerequisite to the efficient operation of many types of process equipment. This problem has been particularly pressing in the operation of multieffect kraft black liquor evaporators where entrainment separators of several types have been designed, re-designed, and re-located in recent years. The fact that economy of operation has become paramount to continuing operation in our competitive industry as well as the ever increasing concern for adequate pollution control measures has been responsible for our industry and its equipment manufacturers taking note of the work being done by others with York mesh demisters (*1*).

This work has pointed out several factors which make these entrainment separators particularly appealing:

1. They represent a low first cost investment.
2. Normally no extensive modification to existing equipment is required to install them.
3. No additional direct horsepower is required by their operation.
4. They do not usually require changes in the method of operating equipment on which installed.

The method by which these pads remove entrained mists is quite simple (Fig. 1). The pads are installed in the vapor space over a boiling liquid in such a manner that all of the vapor must pass through the many layers of woven wire mesh. Droplets carried by the vapor stream collect on the wires where they agglomerate until they possess sufficient mass to overcome the vapor velocity and fall back into the liquid while the mist-free vapors continue on through the pad. Our work indicates that a second reaction of refluxing is probably taking place. This will be discussed later.

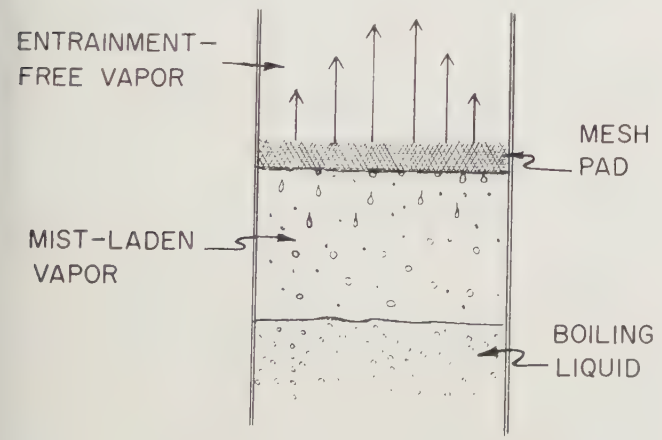


*Fig. 1. How they work*

H. D. JURGENSEN, Pulp Mill Chief Chemist, North Carolina Pulp Co., Plymouth, N. C.; H. E. JACOBY and H. G. LANKENAU, Chicago Bridge & Iron Co., New York, N. Y.

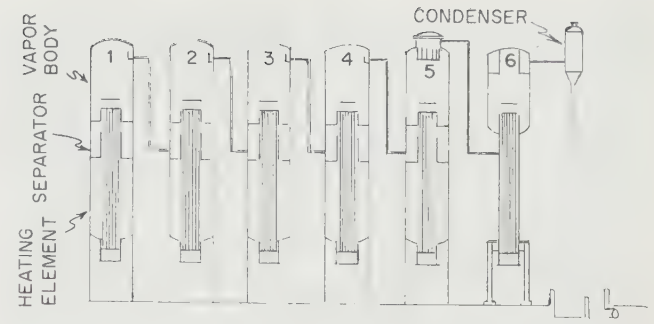


*Fig. 2. Tower type self-supporting evaporator with integral separators*

North Carolina Pulp Co. first became interested in this new approach to entrainment separation during the spring of 1958. This interest was stimulated by the poor operation of the no. 4 set of evaporators. Condensate soda losses were exceeding one pound per ton, and a short period of 12 days between boilouts was causing a loss in overall capacity.

This set was originally a five-body quintuple-effect set with internal wrap around separators. In 1955, a sixth body was installed which contained a conventional separator in the dome ahead of the barometric condenser (Fig. 2).

When the operating trouble developed, a thorough top to bottom inspection was made which showed that corrosion cracks had developed in the bottom plates of the internal separators (Fig. 3). This condition permitted all entrainment entering the separator from the preceding body to collect in the condensate of the receiving body. Repairing the separators would have required the removal of the outer shell and some of the vapor piping, which would have been a costly and time consuming undertaking.

When the evaporator manufacturer was consulted for recommendations, they suggested the possibility of installing mesh entrainment pads. At this same time we began receiving information from Weyerhaeuser's mill, Springfield, Ore., concerning their mesh pad installation. The reports indicated that the mesh pad entrainment separators were producing good results on liquor from west coast pulping operations (*2*); and although we had some reservations concerning the application on Southern liquor, the decision was finally made to equip all six bodies with full dome area pads.

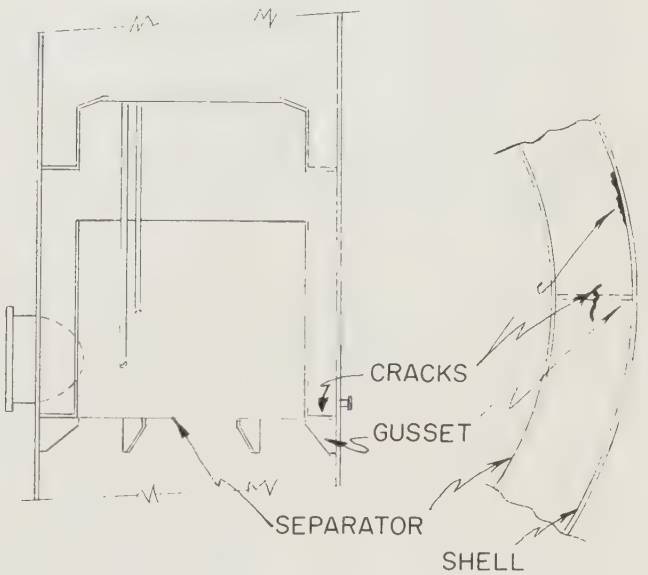


*Fig. 3. Detail of wrap-around separator*

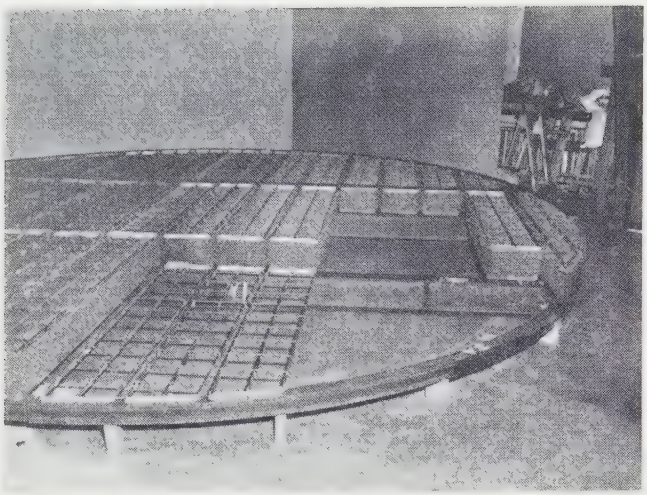

*Fig. 4. Makeup and installation of pads*

The evaporator manufacturer recommended the installation of two types of 6-in. pads—No. 931 (a high throughput type) for no. 1 body, and no. 421 (a high efficiency type) for nos. 3–6 bodies. A special combination pad was recommended for no. 2 body. This special pad was made up of 3 in. of No. 931 on the bottom and 3 in. of no. 421 on the top. Figure 4 is a view of the pads showing their makeup and how they are installed. All of our pads are type 304 stainless steel and are constructed in sections from 12 to $14^1/_2$ in. wide and of varying length depending on vapor body dimensions. Steel grids are fastened to the top and bottom of each pad to give rigidity and to provide fastening points during installation. These grids are type 304 stainless steel in no. 1 and no. 2 body and carbon steel in the remaining four bodies. When received the pads were all properly sized and shaped to fit the vapor body.

Preparing the vapor body for pad installation required that an annular support ring of angle iron be welded to the inside wall of the vapor body at the desired height above the tube sheet. Because of the large diameters involved I beam cross members were also added to prevent sagging of the pads. The pads were then placed on top of these supports according to their assigned position and finally wired in place. Figure 5 shows the location of the pads at the completion of the installation. No special techniques or equipment were required to make this installation nor were any sections of the domes removed to permit placing the pads properly. Manway openings provided a very convenient means of getting the pads into the vapor bodies.

This set was put into operation on Sept. 13, 1958. From that date the success of the entrainment pads became more apparent with each passing day. Soda losses in the condensate dropped to less than 0.1 lb. of salt cake per ton, pressure drop across the pads was less than expected with a total drop of about 1 in. of mercury for all separators combined, and the daily B.O.D. load of our combined evaporation effluent dropped 100 p.p.m. Added to these improvements is the fact that on the initial run this set operated for 94 consecutive days without a boilout. During that extended run, product liquor concentration dropped only 2° Bé. Subsequent runs of 60 days have been made which show a 3° Bé. drop in product liquor and a feed rate reduction from 440 to 350 g.p.m.

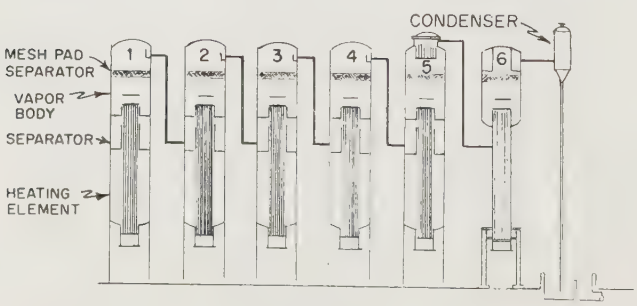


*Fig. 5. Tower type self-supporting evaporator with York mesh demisters*

A tabulation of pressure and pressure differential readings for current operation is shown in Table I. These data are averages of eight sets of readings with four sets taken just before a boilout and another four sets taken just after the boilout. They show that the pressure drop across the pads in the first five bodies totaled just 1% of the overall pressure drop and only one third of the total vapor system drop.

Current operating practice provides for reading the pressure drop across the pads on a twice weekly schedule. Whenever the drop across one pad approaches 1 in. of mercury the pad is washed for 5 min. with a full cone spray nozzle located above the pad at the proper height to cover the entire pad, as shown in Fig. 6. This washing is done on the run and is necessary about once every 3 or 4 weeks. It is interesting to note that on the run spray washing is required on no. 4 body more often than any other body. This is probably due to higher foaming tendencies on this body. As a rule no. 3 pad is spray washed at the same time as no. 4, as it is the only other body which normally shows an appreciable pressure drop.

The overall results of this installation were so satisfactory that in November of 1958 a survey was made of the remaining four sets of evaporators to determine which set could be improved the most by mesh pad separators. This survey showed that our no. 3 set was losing in excess of 500 lb. of salt cake per day through the condensate system and was averaging just nine days between boilouts.

This set, like no. 4 set, was originally a five-body quintuple-effect set. It was equipped with external centrifugal catchalls and a surface condenser. In 1955 a sixth body equipped with a Chicago Bridge and Iron patented integral separator was added to provide sextuple operation (Fig. 7). This set was normally operated at 53,000 lb. of total solids per hour which is equivalent to about 450 pulp tons per day for our operation.

When all factors were considered this set showed the greatest possibility for improvement by mesh pad separators. Our experience up to that time on no. 4 set had left many questions unanswered, however, so it was decided that a program of gradual conversion to mesh pad separators would be adopted so that a study of results could be made for each step

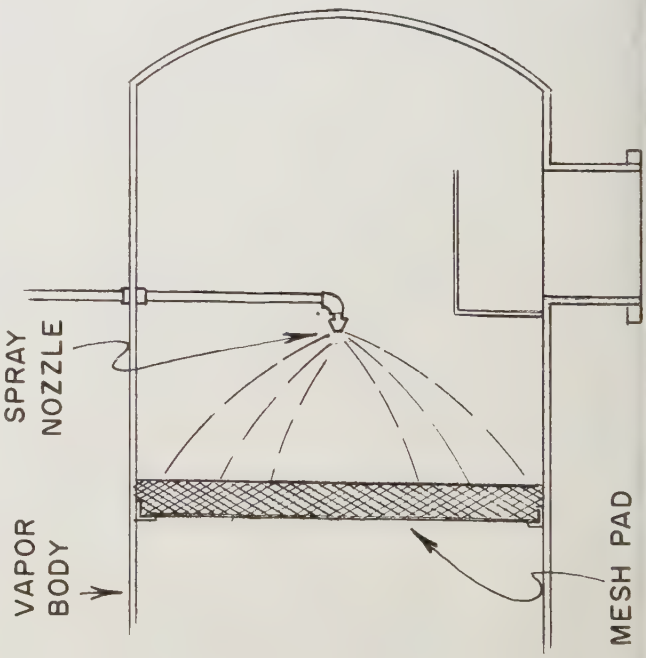


*Fig. 6. Spray wash arrangement*

**Table I. Pressure and Pressure Differentials of No. 4 Evaporator**

Inches of Mercury

| Effect no. → Item | 1 Chest | 1 Dome | 2 Chest | 2 Dome | 3 Chest | 3 Dome | 4 Chest | 4 Dome | 5 Chest | 5 Dome | 6 Chest | 6 Dome | 1–6 Total | Per cent of Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Press. reading | 93.7 | 52.6 | 52.1 | 27.4 | 27.2 | 15.3 | 14.2 | 8.6 | 8.0 | 5.2 | 4.9 | 2.9 | 90.8 | |
| Press. drop chest$_A$-dome$_A$ | 41.1 | | 24.7 | | 11.9 | | 5.6 | | 2.8 | | 2.0 | | 88.1 | 97.0 |
| Press. drop dome$_A$-chest$_B$ | 0.5 | | 0.2 | | 1.1 | | 0.6 | | 0.3 | | 2.7 | | 3.0 | |
| Across pads | 0.39[a] | | 0.04 | | 0.12 | | 0.29 | | 0.07 | | 0.91 | | 1.0 | |

[a] Bouncing manometer, av.

of the program as it was completed. The adopted program consisted of the following steps:

Step I. Normal operation of sufficient duration to permit collection of representative operating and condensate data.
Step II. Install pads in no. 4 and 5 bodies to replace nos. 4 and 5 external separators. Collect representative data.
Step III. Install pads in no. 3 and 6 bodies. Remove no. 3 catchall. Collect operating data.
Step IV. Install pads in no. 1 and no. 2 bodies. Remove catchalls and complete collection of data.

Figure 8 shows the set after completion of the program. Operating time between each step was arranged to provide for the collection of 12 sets of data relative to condensate quality and mesh pad performance for each successive paired installation. Table II gives the average condensate quality

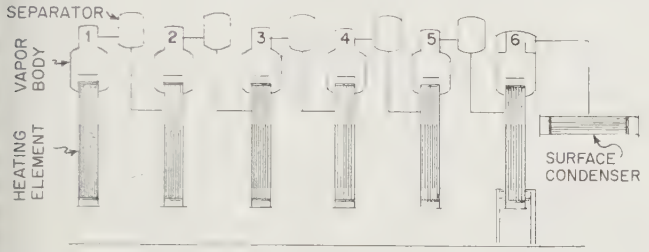


*Fig. 7. No. 3 evaporator set with external catchalls on first five bodies*

data for each of the four steps. The subheadings vapor no. 1, vapor no. 1–5, and vapor no. 6 indicate the condensate source. The conductivity values show that condensate quality was improved with each successive step of the installation program on all effects except no. 6. When compared with the soda content there appears to be some correlation between the two values for the first five bodies but none for no. 6. On the basis of these data it would seem that the conductive substances in the condensate from no. 6 body are not entrained soda but perhaps some distillable constituent of the liquor.

One of the more interesting aspects of these data is shown in the condensate pH values which all increased as the program proceeded. This phenomenon is not in agreement with the results reported by Morgan (*2*), and is not in agreement with the generally conceived idea of decreasing pH values with decreasing soda content. It was mentioned earlier that a second reaction, that of refluxing, was probably occurring in the pads. We feel that refluxing within the pads is causing the removal of certain acidic constituents from the vapor stream and returning them to the liquor rather than permitting their solution in the condensate and thereby depressing the pH. It is possible that this condition is at least partially responsible for the increased operating time between boilouts. A complete study of this possibility might provide some interesting new approaches to black liquor evaporation.

B.O.D. reductions, which were expected of this installation, have not been realized up to this time. A 10 to 15% increase in evaporation rate has been possible, however, which may explain the lack of B.O.D. improvement. We believe that continued work with the pad operation may possibly produce the B.O.D. reduction. This is being studied at the present time.

Table III, which is a summary of the temperature drops and pressure losses occurring during each step of the conversion program, points out an interesting aspect of this installation. It should be noted that the average evaporation rate was increased for each step through no. 3. Total available temperature drop from the chest of no. 1 body to the dome of

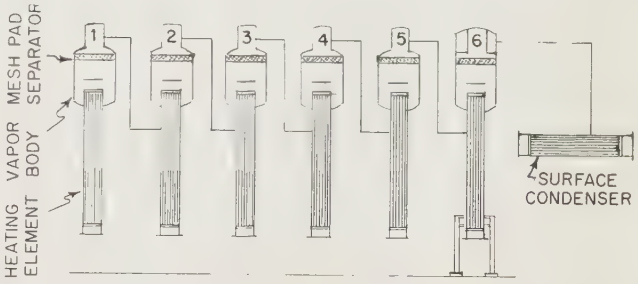


*Fig. 8. No. 3 evaporator set with external catchalls removed and mesh pad type separators installed in all bodies*

no. 6 body was increased for each of the four steps through higher steam pressure and increased vacuum. Temperature-drop data for the vapor system show an undesirable increase as the number of pads installed was increased until step IV, when all bodies were operating with pads at which time it decreased.

Data on pressure drop across the pads (Table IV) show they were negligible and not responsible for the increased temperature drop. It became obvious then that the temperature drop in the vapor system was related to the evaporation rate. An analysis of the vapor system finally uncovered the cause in the vapor inlet to each heating element. This inlet consists of two concentric shells 3 in. apart surrounding the top of the tubes. As evaporation rates were increased the increased volume of vapor entering each of the heating elements developed turbulence and back pressure thereby increasing the temperature drop in the vapor system. This condition has offset some of the improvement expected of the pads and points out the fact that the installation of mesh pads will not offset equipment shortcomings inherent in their design.

While the results of pad installation on the no. 3 set of evaporators have not been as outstanding as on the no. 4 set, the overall effect has been an improvement in soda losses, con-

**Table II. Condensate Quality Data on No. 3 Evaporator Set**

| Step number | Evaporation Lb/hr. | Conductivity, mhos × $10^{-6}$: Vapor no. 1 | Vapor no. 1–5 | Vapor no. 6 | Condensate pH: 1 Vapor | 1–5 Vapor | 6 Vapor | Sodium, p.p.m.: 1 Vapor | 1–5 Vapor | 6 Vapor |
|---|---|---|---|---|---|---|---|---|---|---|
| 1–No pads ext. separators | 151,000 | 103 | 92 | 271 | 6.5 | 8.0 | 8.2 | 5 | 3 | 6 |
| 2–Pads in no. 4 and 5 bodies | 163,000 | 122 | 83 | 376 | 7.1 | 7.9 | 8.3 | 6 | 2 | 4 |
| 3–Pads in no. 3, 4, 5, and 6 bodies | 169,000 | 107 | 47 | 187 | 6.1 | 8.1 | 8.1 | 4 | 3 | 3 |
| 4–Pads in all bodies | 161,000 | 30 | 70 | 260 | 7.7 | 8.3 | 8.5 | 2 | 2 | 3 |

Table III. Summary of Temperature Drops and Pressure Losses in No. 3 Evaporator Set

| *Step number* | *Evaporation lb./hr.* | *Total available temp. °F. No. 1 chest to no. 6 dome* | *Vapor system temp. drop, °F.* |
|---|---|---|---|
| 1–No pads ext. separators | 151,000 | 121.6 | 9.2 |
| 2–Pads in no. 4 and 5 bodies | 163,000 | 123.4 | 11.3 |
| 3–Pads in no. 3, 4, 5, and 6 bodies | 169,000 | 138.7 | 19.9 |
| 4–Pads in all bodies | 161,000 | 141.5 | 14.7 |

densate quality, and capacity through extended time between boilouts. The two sets of evaporators discussed here represent just 40% of our total evaporation capacity, but we have reduced our daily soda loss through operation of all five sets of evaporators from 2 lb. of salt cake per ton to 0.8 lb. per ton since installation of the entrainment pads. No maintenance has been required on either pad installation to date. The pads show no evidence of deterioriation even though they have been in use for over 1 year on the no. 4 evaporator set. We feel that the results reported here show that the use of mesh pad entrainment separators can provide a low cost means of improving kraft black liquor evaporator operation and are particularly useful where existing separation equipment is in need of extensive, difficult repairs. A continuing program of development should make the pads even more effective and may soon provide the know how to further solve the problem of evaporator entrainment.

Table IV. Pressure Differentials Across Pads

Inches of Mercury

| *Evaporation lb./hr.* | *No. 1 pad* | *No. 2 pad* | *No. 3 pad* | *No. 4 pad* | *No. 5 pad* | *No. 6 pad* | *Total* |
|---|---|---|---|---|---|---|---|
| 152,000 | 0 | 0 | 0 | 0.25 | 0 | 0 | 0.25 |

## SUMMARY

Wire mesh demisters can be used satisfactorily on all effects of multiple effect evaporators concentrating black liquor from southern pulping operations.

Entrainment losses can be reduced with a resultant reduction in B.O.D. loadings and an increased operating period between boilouts.

Maintenance requirements have been nonexistent during the first year of operation.

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Received Nov. 9, 1959. Presented at the 13th Alkaline Pulping Conference of the Technical Association of the Pulp and Paper Industry, held in Jacksonville, Fla., Nov. 4–6, 1959.

# Appraisal of the Design and Construction of Horizontal Size Presses

HERMAN A. SMITH

One of the sections of the paper machine that presents a picture of complete simplicity is the size press. The process appears to go along with no inconveniences and the mechanical equipment required looks elementary in design.

In practice, the sizing of paper requires a knowledge of chemistry, an analytical mind, and the patience to cope with a long list of conditions we call papermaking variables.

We shall not touch upon the chemistry. We shall study the mechanical aspects, focusing particular attention on the horizontal size press.

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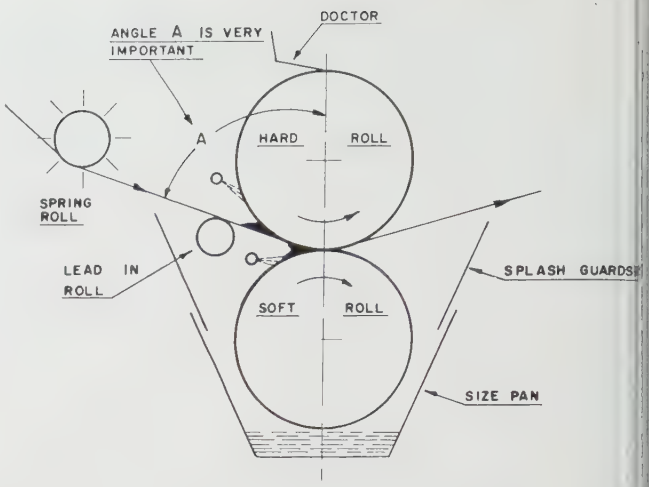


*Fig. 1. A conventional vertical size press for book, bond and offset*

To have the press rolls in a horizontal plane represents a comparatively recent digression from conventional design. Since all of its merits and weaknesses are not immediately obvious, a realistic analysis is advisable.

## DISADVANTAGES

To better understand the design features of the horizontal size press, we must first refer to its vertical counterpart in Fig. 1. This arrangement is generally accepted as standard for surface sizing bond, book, and offset. For certain high rag content papers, the old style tub with submerged paper leads has not yet been superseded.

A serious disadvantage in the vertical press is the ingoing paper lead which must support a pond of size. It may or may not be a disadvantage to have the top side of the paper sized ahead of the wire side. It can be a disadvantage to have the two sides exposed to the liquid over unequal areas before applying pressure. Both conditions will exist when the angle of the approach lead is not determined with care.

Another serious defect in the vertical press is the difficulty in controlling the surplus liquid leaving the nip. Numerous schemes have been devised to overcome this; but the success has been less than noteworthy.

## THE HORIZONTAL SIZE PRESS

In Fig. 2 we have the horizontal press. The approach lead, being vertical and downward, makes paper passing through the nip automatic. No press housings or supporting rolls

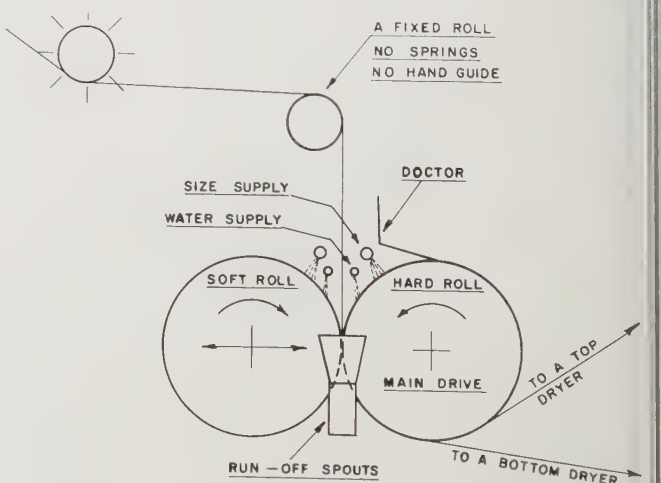


*Fig. 2. Recommended arrangement of a horizontal size press*

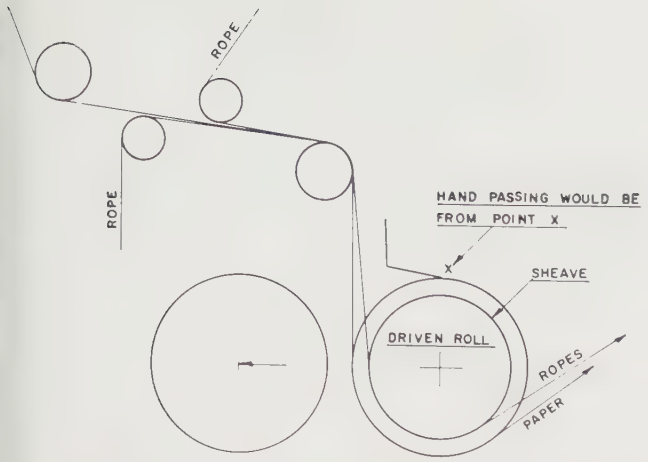


*Fig. 3. Nip open during a bypass; paper carried through on ropes*

Alternate. Close nip and substitute plain water for size.

interfere with handling the tail before or after the nip. The sheet supports nothing but its own weight. The web tension can be appreciably reduced. Breaks are less frequent. The ponds on both sides of the paper are controllable and at one level. The run-off is handled with minimum throwing and without a size pan or splash guards.

### *Which Rolls Where*

As we study this press, two major questions come to our mind and the first is: "Which of the two rolls should be the hard one?"

In the process of sizing paper, the relative positions of the hard and soft rolls appear to have no significance. The answer to our question will be found when the paper breaks in the size press. It is likely to adhere to the hard roll and if this is in the first position, the broken sheet will turn toward the wet end. The second position, therefore, becomes logical for the hard roll.

In this connection, we should remember that even though desirable, all size presses do not have carrier ropes. The paper must then be passed by hand and the second roll is certainly the preferable point from which to pass to the after driers.

Strong emphasis is sometimes placed upon interchangeability of rolls in the horizontal press. The reason for this is the accessibility of the main bearings. Except in an emergency, it is not probable that a mill will want to replace or interchange press rolls between weekends. If this is ever necessary, the down time will be a minimum since we have no housings, top press roll, or other obstructions.

### *Which Roll Driven*

Our second major question is: "Which roll should be driven?" The answer will be found in the bypass. This can be done in several ways, the first being to carry the sheet overhead, clear of the press. This is a satisfactory lead so long as no attempt is made to rethread the carrier ropes. It is not interesting to this commentary.

In another bypass, the paper is threaded through the press in the usual manner with no change in ropes. As decided by the operator, the rolls may be opened for dry operation as in Fig. 3, or closed, with plain water in the pond. The open nip strongly suggests that the drive be on the second roll.

The closed nip with water is preferable if overdrying in the aftersection is to be avoided. A hurried glance at this by-pass might make it appear that to drive either roll would be acceptable. However, we must not forget that if a doctor is used, it will be on top of the second roll and a doctored roll should be driven.

The opinion has been expressed that when we have a pair of contacting rolls, the soft one should always have the drive. We have never found any condition to substantiate this belief which would contradict the smoothing press.

### *Roll Crowns and Pressures*

Since neither roll must support the other in the horizontal press, a new concept of crowns and pressures is presented. Assuming that the rolls are well engineered, the natural deflection becomes of negligible concern. It can be assumed with safety that both deflect approximately the same amount.

With the proper crowns and a good hydraulic or pneumatic system, the nip pressure can be reduced to the equivalent of the weight of the movable roll or even less. A natural result is increased size pickup and better graduation thereof.

### *Helper Drive*

If the nip pressure is very low, the movable roll may require a helper drive. Many experienced operators will question this. Nevertheless, it is difficult to see how it can be avoided if the fullest advantage is to be taken of very low pressures, increased pickup and still avoid irregularities in the surface speed of the undriven roll.

### *The Doctor*

No detail of any size press is more controversial than the doctor. The introduction of the horizontal press has done nothing to clarify the diverging opinions. For some papers a doctor may be superfluous, for others, a necessity.

### *Outlet Spouts*

In the design of the outlet spouts, there is less mystery than might be imagined. These should be V shaped with the small diameter placed below the tangent point of the press rolls. They should be close to but not in contact with the roll ends. An opening must be provided to receive the cascading liquid. The front spout must clear the ropes and be movable for paper passing.

### *Ropes and Threading*

In Fig. 4 we see a very satisfactory rope lead. Small sheaves are preferable since their locations are easily adjusted, their combined weights insignificant, and their bearings can be protected.

One of the operating conditions practically impossible to predict when designing this press concerns the passing of the tail by ropes. For a few seconds it follows the ropes out beyond the roll faces. It gradually works its way between the rolls toward its normal alignment. If the normal volume of size is allowed to flow during that time, the tail becomes saturated and can be torn at the spreader roll.

This is a wasteful operation not only in lost time, but too much size is lost with the front spout out of position. A good

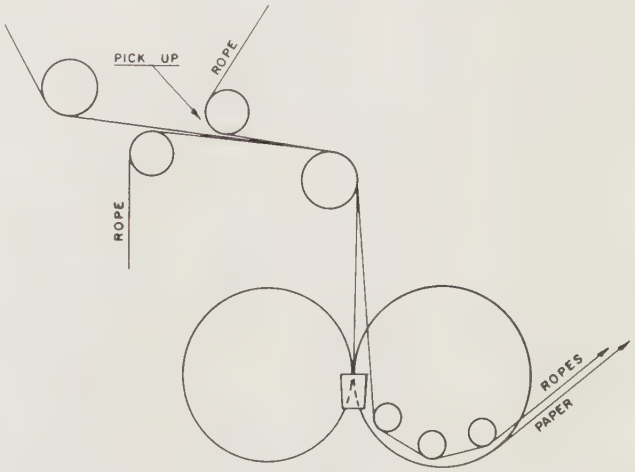


*Fig. 4. Rope leads recommended for the horizontal size press*

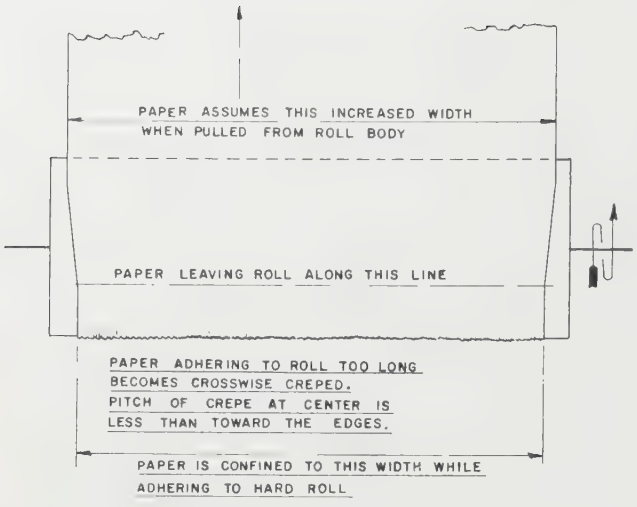
PAPER ASSUMES THIS INCREASED WIDTH
WHEN PULLED FROM ROLL BODY
PAPER LEAVING ROLL ALONG THIS LINE
PAPER ADHERING TO ROLL TOO LONG
BECOMES CROSSWISE CREPED.
PITCH OF CREPE AT CENTER IS
LESS THAN TOWARD THE EDGES.
PAPER IS CONFINED TO THIS WIDTH WHILE
ADHERING TO HARD ROLL

*Fig. 5*

remedy is to shut off the size but admit just enough water to keep the rolls wet. Wetting of the tail will still take place, but it will be reduced so that the chance of breakage is practically nil. This condition does not exist when the paper is hand passed.

### *Too Much Contact*

Another condition that can give trouble is the long arc of contact following the pressure nip. For some papers and speeds this will cause a crosswise crepe which the expanders will not remove. The markings may still be present after calendering.

The instant a sheet is remoistened, it must expand in every direction. Pressed against a roll, it does not have freedom of motion and crosswise creping results. Figure 5 shows this condition. When entering a top drier, this arc of adhesion is critical. Entering a bottom drier, it is lessened. The positive way to prevent such sheet damage is to introduce a lead-off roll as in Fig. 6.

### *The Press Rolls*

The first requisite for the press rolls is that both must be exactly the same face, terminating in a sharp 90° edge. To have one longer than the other seriously hinders the clean flow of the size. If liquid is thrown from any roll, it comes from the flat ends and not the periphery. A slight radius on the edge of either roll will cause additional throwing from the faces. To prevent interference with the spouts, the ends of the rolls should be flat rather than conical.

Since lower pressures are anticipated, the press rolls should be well balanced statically or dynamically, as the paper speed demands. Theoretically, the diameters can be smaller for a horizontal press, but in reality this is doubtful. Even though the rolls are self-supporting, good engineering design is essential. The diameter is often dictated by interchangeability with existing equipment and old rolls may be used.

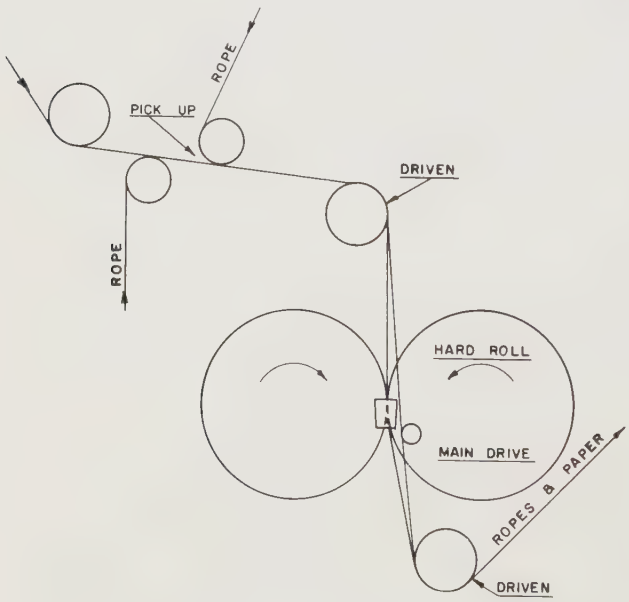


***Fig. 6. Preferred threading of paper and ropes; contact angle of paper on hard roll is reduced***

Lead-off roll is placed so that paper will follow hard roll slightly before peeling.

## SUMMARY OF ADVANTAGES

The horizontal size press is ideally suited to lightweight papers.

The paper supports nothing but its own weight.

There is no danger of "bagging."

Reduced sheet tension in the approach lead means safer running.

Passing the paper into the nip is simple and free from hazard for the operator.

Timing of size application is identical for both sides.

Area of application is identical for both sides.

The pond level is easily controlled.

Reduced nip pressure means greater size pickup and better control thereof.

Reduced nip pressure and fewer breaks make roll grinding less frequent.

Removal and replacement of press rolls greatly simplified.

Throwing of size is reduced to an all-time low.

With a good air or hydraulic pressure system, nip pressures can be accurately evaluated and, if necessary, duplicated.

## WORDS OF CAUTION

Do not speak of the rolls as "top and bottom." The nomenclature is hopelessly confusing.

Do not mount the lead-in roll in springs. Leave the spring roll on the drier section.

Do not make the lead-in roll a Mount Hope. The wrap is too great.

If you feel that an expander is necessary, put it ahead of the lead-in roll. In that position, it can be useful for an overhead by-pass.

There is not much need of the lead-in roll being in a hand guide unless the driers are out of alignment or the paper has a slack edge.

Whether you lead into a top or bottom drier will depend upon the general arrangement of the after-section more than on any other factor.

We have not found any evidence to prove that either is preferable.

The length of the off-going paper lead is not influenced by changing the press rolls from a vertical to a horizontal plane. This must be decided by such factors as speed, makeup of the sheet, basis weight, bulk and absorbency, moisture retained, extent of penetration required.

In reality, a time element is involved. Usually, a longer lead is preferred since it allows for a major percentage of the inevitable sheet expansion.

Expansion of paper by re-wetting is a natural phenomenon that cannot be prevented. This will tend to reach out to its own limits. Attempts to restrict or prevent it can have troublesome consequences.

On a very short off-lead, the effectiveness of the spreading devices is impaired. Wrinkling can carry over beyond the expander and the first after drier.

If you hope to convert a vertical press to a horizontal, look closely at the old rolls.

Both must be of a design that can be re-worked. Besides having the faces machined to one common dimension, the

necks may have to be re-shaped to admit the overflow spouts.

Both rolls must be interchangeable.

The drive side journals of both should be extended.

All size press rolls should be in good static balance.

If the old press rolls have no antifriction bearings, they will be essential for the horizontal press.

It is not wrong to describe the operation of a horizontal size press as "clean." Nevertheless, this desirable condition can be sharply reversed if the overflow spouts are not carefully designed.

Do not expect to save any floor space by the use of a horizontal press.

If you intend to convert an old vertical press to a horizontal, study carefully your present spacing and compare it with what you hope to have. You may have to move your drive.

Whether or not you drive both rolls must depend upon your anticipated nip pressures and the static balance of the rolls.

Slippage must be avoided.

The longer the wet sized sheet is allowed to remain in close contact with a press roll, the greater the chance of damage by crosswise creping.

Although the nip pressures are at a reduced level, it is still necessary to inspect and recondition the press rolls periodically.

The last drier before any size press is the limit of your drying capacity. The after-driers add nothing to it. They only remove the moisture added by the press.

### THE PRECALENDER

It is not easy to make a study of the horizontal size press without giving some thought to another unit almost as new. We refer to what this writer has chosen to call the precalender. The idea of a calender ahead of the size press probably had its beginning in on-machine coating where an application of pressure adds greatly to the quality of the coated sheet.

In a certain mill of our acquaintance the results obtained from the use of a precalender justified the cost of installation, far beyond expectations. The applied pressure tended to iron out the two-sidedness. It also leveled off the moisture content across the sheet which had previously shown substantial tapering off toward the edges. This resulted in more uniform size pickup. Coupled with the increased pickup in the horizontal size press, this made the combined installation well worth while.

### EPILOGUE

It is universally known in our industry, that every statement, even faintly resembling a rule, must have at least one exception. We have seen several horizontal size presses whose arrangement was in obvious disagreement with the thoughts we have expressed here.

When we encounter such divergence of opinion and operating conditions, it is usually best to make a new approach. We must seek out the features that are correct in theory even though very new. We must combine these with others we know have a background of sound prior practice. Such has been the purpose of this paper in our study of the horizontal size press.

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**Fourteenth**

**Alkaline Pulping Conference**

**Multnomah Hotel**

**Portland, Ore., Aug. 22–24, 1960**

# A Direct Reading Pulp Consistency Tester

CLAUDE L. RUCKER, JR.,
and JEROME LANCASTER

Consistency testing of thick pulps of 3% and above has long been a problem, both in the time required to perform the test and in the accuracy of the test. The method which appears to be standard throughout the industry is to weigh a sample of pulp slurry, filter it, and dry the pulp to determine the consistency. The time required for the test is usually a minimum of 15 min., and the accuracy of the test is unreliable. The difficulty in running an accurate test has been demonstrated by careful tests in our laboratory. Frequently, duplicate tests differ by 0.2% or more. On routine testing, the error is considerably greater. Human errors are great enough in many cases that the test is of little value, which results in considerable confusion in our overall consistency control system.

Consistency control is important throughout the process, particularly so in the screen room, at the refiners, and at the stuff boxes supplying the paper machine. Variations at any of these points can cause difficulties at the wet end of the machine and affect the liner board quality. For effective screening, a constant amount of stock must be supplied to the screens. This can only be done with a pulp of a constant consistency. In the refiner room, changes in consistency will cause changes in the refiner stock through-put. This causes variations in refining, which result in over- or underrefined stock. Variations in refining will have a variable affect on the drainage properties of the stock on the wire and, consequently, on the moisture and mullen properties of the finished board. At the stuff boxes, any change in consistency will, of course, affect the basis weight of the board.

The time element is important for checking pulp freeness. Particularly so in our case at the refiners. We use a modification of TAPPI R.C. #108 in which the pulp is diluted to 1% for a drainage test. This test is used as a control on our primary refiners. In times of trouble, where we felt the refiners were out of line, a quick test could not be made because of the time required to test the consistency, prior to checking the drainage. Also, a quicker method for determining consistency would allow more frequent routine testing of the pulp drainage from refiners in order to maintain a more uniformly refined stock.

In order to have the control needed at these critical points, a quick method of reading the stock consistency directly within a reasonable degree of accuracy was highly desirable.

### CONSISTENCY TESTER EQUIPMENT

The most direct approach appeared to be to design a mechanical tester to measure the consistency by measuring the torque produced by agitating stock slurries. After working with and testing several different types of equipment, we selected the ELB variable-speed agitator, manufactured by Chemineer, Inc. The agitator, as shown in Fig. 1, mounts on a thrust ball bearing on a dynamometer stand. The moment arm is attached to a pneumatic, differential pressure transmitter, which transmits the signal to a 3 to 15 p.s.i. receiver gage. The gage will supply a numerical value proportional to the torque produced. For the development work in this report, a chart recorder was used instead of the receiver gage. Both instruments worked equally well in measuring torque. We have recently replaced the recorder with the receiver gage, because of the gage being less expensive and requiring less space.

For agitating the stock, 4- and 2-blade impellers, 6 in.

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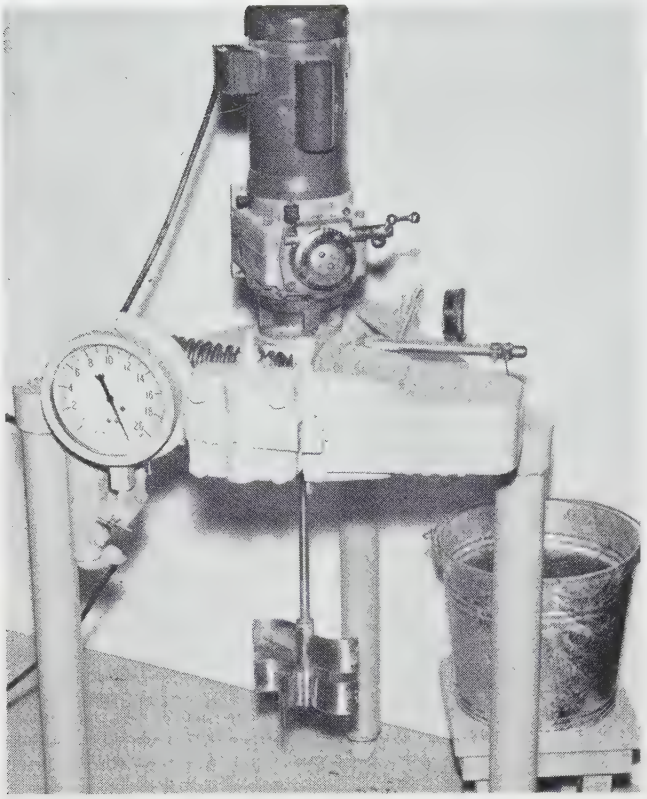

*Fig. 1. Chemineer ELB agitator*

diam., were prepared. Blade widths of 2 in. were found the most satisfactory. The 4-blade impeller produced the widest range of torque measurements, making it the most suitable. With some of the lesser refined stocks, the stock appeared to dewater with agitation. Using the 2-blade impeller on top of the 4-blade impeller kept the stock uniformly mixed. The optimum speed for good mixing was found to be at speed setting 7.

For a sample vessel, a 12-qt. bucket proved satisfactory. The bucket was filled to a depth of 7 in. with stock. The bucket of stock was placed on a platform $9^1/_4$ in. high, which

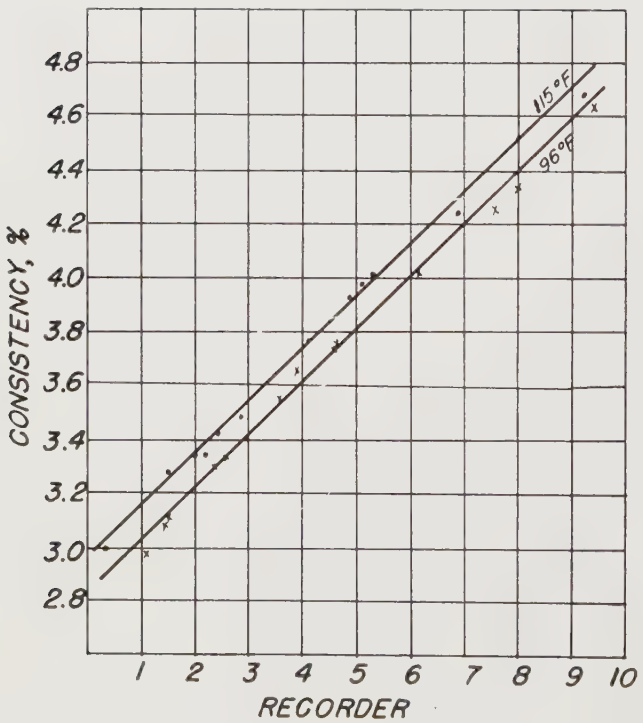


*Fig. 2. Stock prior to machine refiners*

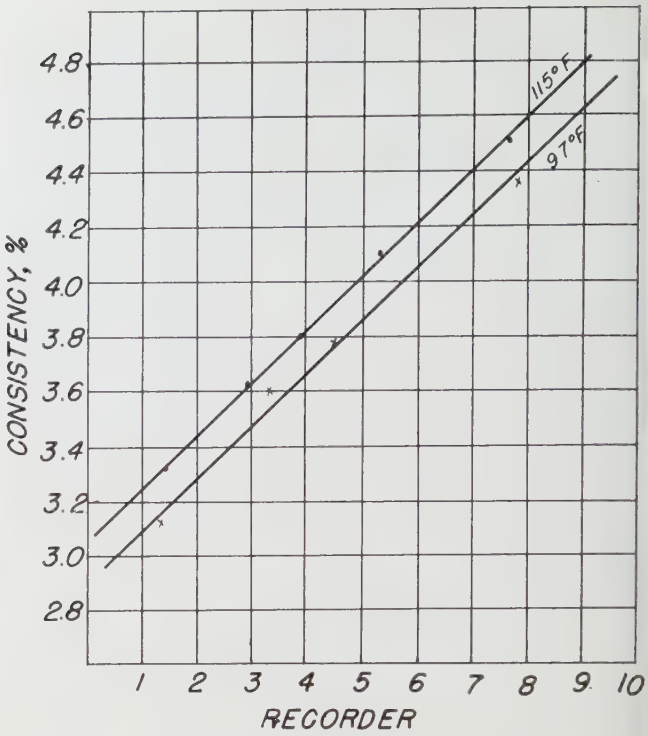


*Fig. 3. Bottom liner refined stock*

located the 2-blade impeller about $^1/_2$ in. under the surface of the stock.

## DATA AND RESULTS

Preliminary work indicated that it is possible to correlate the torque measurement with the consistency of stocks ranging from 3 to about 4.5% consistency. However, factors other than consistency were found to affect the torque measurements, introducing errors in the test. The variables were: loss of torque with agitation, temperature of stock, refining of stock, and volume of sample.

*Loss of Torque.* A loss in torque amounting to about one unit on the chart was found during the first few minutes of agitation, and began to level off after 3 min. of agitation.

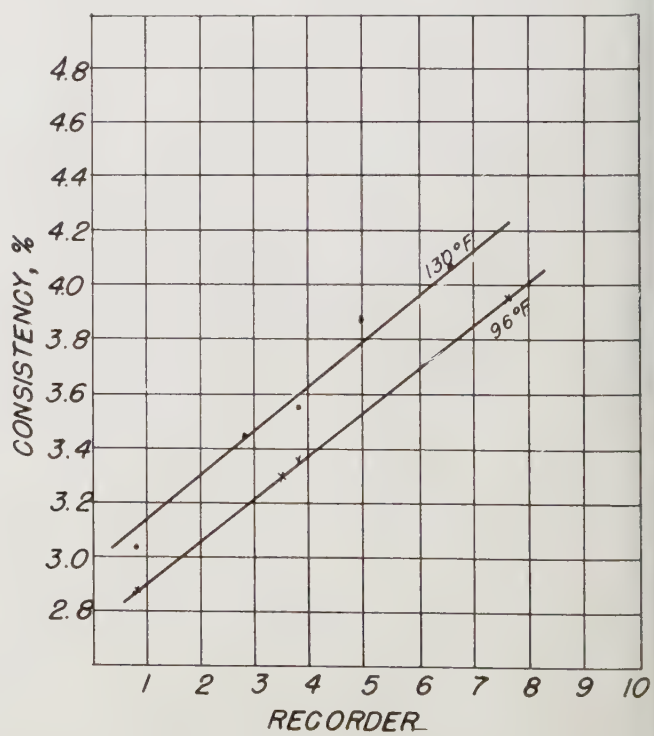


*Fig. 4. Top liner refined stock*

This action is probably explained by the high rate of shear. The speed setting of 7 on the agitator is equivalent to about 250 r.p.m. At high shear rates, pulp fibers gradually align in the same direction as the flow, which results in a loss of torque. In order to standardize this variable, the torque measurements are taken after 3 min. of agitation.

A loss in torque was also noted in high pH stocks containing considerable air or foam. Defoamer is added to all samples caught in our process prior to the screen room, where the stock production is treated with defoamer.

*Stock Temperature and Degree of Refining.* In order to determine the affect of stock temperature and refining, samples were tested from different levels of refining at known temperatures. Our major levels of different refined stock are:

| | |
|---|---|
| Washer stock | 650 drainage |
| Primary refiner stock | 550 drainage |
| Bottom liner stock | 350 drainage |
| Top liner stock | 100 drainage |

Samples were tested from these points and also from the consistency regulator supplying the bottom liner refiners. Stock from this regulator is of the same refining as the primary refiners, but it is located after the screen room. The samples were tested at 100 and 120°F. After agitating the stock for 3 min., the temperature dropped several degrees. For the calibration the temperature was taken after agitation, at the same time the torque measurement was recorded. The actual consistency was determined on each test by drying the entire sample.

It was found that the samples tested from the washers, primary refiners, and the consistency regulator prior to the bottom liner refiners, compared closely enough to be plotted on the same correlation curve of consistency versus recorder readings. These data are illustrated in Fig. 2, showing the correlation at 96 and 115°F. The temperature correction amounts to 0.008% consistency per °F. or 0.04% consistency per 5°F.

Bottom liner refined stock has a slightly different correlation curve. This correlation is shown in Fig. 3. The temperature correction amounts to 0.009% consistency per °F. or 0.045% consistency per 5°F.

Top liner refined stock shows the most pronounced change in torque measurements, due to refining. The correlation of consistency with recorder readings is shown in Fig. 4. The temperature correction amounts to 0.007% consistency per °F. or 0.035% consistency per 5°F.

Each of the different stocks have about the same temperature correction. Allowing an average of 0.04% consistency change per 5°F. would be well within the experimental error of the calibration.

In order to correct for the effect of refining, sampling in our case will have to be classified into three groups:

1. Stock, prior to paper machine refiners.
2. Bottom liner refined stock.
3. Top liner refined stock.

A curve correlating % consistency with recorder readings for each of these groups, interpolating the consistency at 100°F., is plotted in Fig. 5. The temperature correction can be made by taking the stock temperature immediately after agitation and adding 0.04% consistency for each 5°F. above 100°F.

*Sample Volume.* Another suspected variable in using the consistency tester routinely is variation in volume of sample. The calibration tests were all run in a 12-qt. bucket at a volume approximately 7250 ml. In normal routine testing, the volume of sample will not be as carefully measured. To determine the magnitude of error expected in volume changes, several samples were tested below and above the 7250 ml. volume. The stock tested was taken from the consistency regulator supplying the bottom liner refiners at 105°F. A curve, interpolated to 105°F., is plotted in Fig. 6 from data in Fig. 2, to obtain a standard curve for the comparison of samples of irregular volumes.

As shown in Fig. 6, the samples significantly in error are those of lower than standard volume, i.e., 6050, 6600, and 6750 ml. These samples deviated from the curve by 0.24, 0.14, and 0.13% consistency respectively. In these cases, the top impeller was not covered with stock. At the standard volume, the impeller is covered about 1/2 in. All of the other samples of volumes up to 900 ml. above the standard volume correlated within 0.05% consistency of the curve. This data indicates that reasonable variations in volume above the standard show no appreciable effect on the test. However,

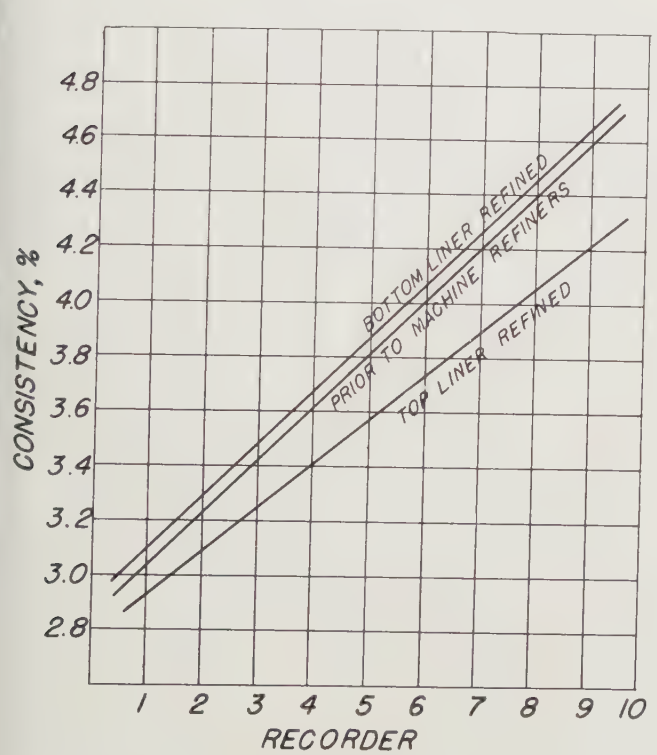


*Fig. 5. Per cent consistency vs. recorder, 100°F.*

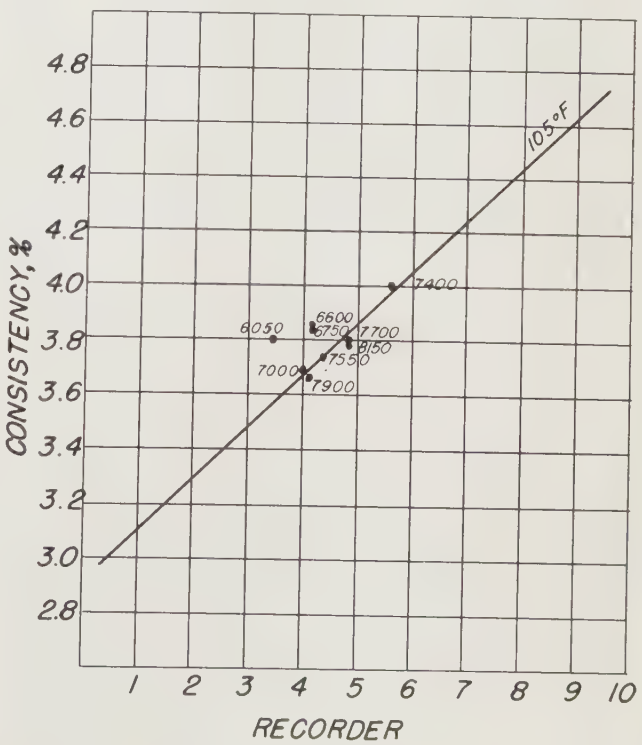


*Fig. 6. Effect of sample volume, ml.*

care should be taken to have sufficient stock to cover the impeller.

A standard sample vessel would probably aid the accuracy of the test, although for routine testing, 12-qt. buckets, marked at the volume desired, appear to be adequate. The data of consistency versus torque measurements in preparing the calibration curves, plotted in a straight line, in all cases with each test being within 0.1% consistency of the curve.

*Results*

As a measure of improvement in accuracy in consistency determination, the data taken from routine testing for one month prior to using the agitator was compared with the month's data following the use of the agitator. These data are compared from tests run on the bottom liner stuff box, because at this point the stock is regulated more evenly than any other place in our process. Prior to testing with the agitator, the average consistency for the month was 3.1%. The tests ranged from 2.3 to 3.9% consistency, a range of 1.6%. The standard deviation was 0.3%. The month following the use of the agitator routinely, consistency averaged 3.2%, ranging from 2.9 to 3.6% or a range of only 0.7% consistency. The standard deviation amounted to 0.1% consistency.

In summarizing, we are now using the following equipment and procedure in our routine consistency testing:

*Equipment.* Chemineer ELB agitator, set at speed 7. Dynamometer stand with transmitter and gage to measure torque. Impellers (6 in. diam.): 4-and 2-blade, 2-in. blade widths. The 2-blade impeller on top.

*Sample vessel.* 12-qt. bucket.

*Platform.* $9^1/_4$ in. high to set sample at desired height.

*Procedure.* Fill a 12-qt. bucket to the level indicated on the bucket (7-in. depth) with the stock to be tested. This volume covers the top impeller about $^1/_2$ in., with the sample bucket located $9^1/_4$ in. high on a platform under the agitator. Agitate the stock for 3 min. Record the torque measurement as indicated on the receiver gage and the stock temperature. Convert the torque measurement into per cent consistency, using the calibration curve corresponding to the point of sampling. Add 0.04% consistency for each 5°F. of stock temperature over 100°F. Report the consistency to the nearest 0.1%.

The test can be run in slightly over 3 min. and should be accurate to 0.1% consistency.

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# The Kraft Pulping of Small Diameter Slash Pines

J. C. McKEE

The past 2 or 3 years have seen an active interest displayed by several southern pulp and paper companies in the utilization of small diameter pines. As treated in this paper, the term "small diameter pine" shall mean pine trees having butt diameters too small for the stems to be classed as merchantable pulpwood. No work has been done in this project on the pulping of small diameter portions of large trees, taken from either the top of the trunk or the limbs.

It has been generally recognized for some time that some stands of young pines have been allowed to grow at undesirably slow rates because of excessive competition among trees for light, moisture, and soil nutrients. The refusal by most mills to accept pulpwood below 4 in. in diameter has made it uneconomical to remove the small trees from such stands. In many instances the expense of removing the trees cannot be justified by the expected growth improvement. This same situation has existed in some stands that have been harvested by the clear cutting method, in which all of the marketable trees in a stand are harvested in one cutting operation. Quite frequently the mature stand of timber includes some trees of an age equal to most of the other trees in the stand but of diameters so small that not more than one stick of pulpwood greater than 4 in. in diameter can be harvested from each tree. Such trees are normally left standing after the harvest cut, and they frequently develop into an undesirable over-story that restricts the growth of the young trees beneath them.

It would be of great help to our land management departments if removing these small trees could be made even slightly profitable with regard to immediate cost and return. Even on a "break even" basis it would normally be advantageous to the land owner to take out the unwanted trees in order to improve the growth of the remaining trees. Only when there is an immediate financial loss involved in harvesting the small trees will there be instances when their removal cannot be justified.

A pulp company will normally not gain as much benefit from small tree utilization on land under outside ownership as on company-owned land. The pulp mills cannot hope for small stem wood to be less expensive than normal-size round wood, on a bark-free, wood weight basis. The small wood is obviously more expensive to handle, and it is doubtful that this high cost item can be offset by low cost of the standing trees. The two major benefits to be hoped for are: (1) a slight increase in the total pulpwood supply, and (2) improvement in pulp company-land owner relationships. With regard to this second benefit, the complaint has frequently been voiced by land owners that the pulp companies teach intense utilization and proper forest management but fail to offer a market for small diameter wood—one of the inevitable products of intensive forest management

In the early discussions of small tree utilization on our company-owned land, the following two questions were quickly developed:

1. How does the quality of this wood compare with that of normal size pulpwood, and could we use it, assuming it could be supplied to the mill at an attractive cost?
2. How good are the prospects of developing economical methods of harvesting and processing the small wood?

It was decided that the first of these questions could be answered more readily than the other, and it was, therefore, the first to be investigated. This paper deals with the study of the characteristics of the small pine stems that influence their desirability as a pulping material. No attempt was made in this project to analyze any of the present methods of harvesting, debarking, or handling the small wood. The study of these generally expensive utilization methods and the development of less expensive methods did not fall within the scope of this project.

Most of the small tree stands owned by Union Bag-Camp Paper Corp. are slash pine stands in the coastal plain area. For this reason, wood of this species (*Pinus elliottii*) and general location was used in this investigation. The study was undertaken in two distinct phases, the determination of the physical characteristics of the wood, and the exploration of its pulping behavior.

## PHYSICAL CHARACTERISTICS

To obtain truly representative samples of the small wood, arrangements were made with our Land Department for the collection of stem samples from ten widely separated forest areas throughout the coastal plain of South Carolina and Georgia. In each of the ten areas selected, five typical trees were chosen from stands of small trees, one section 8 to 10

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**Table I. Physical Characteristics of Stem Samples**

| Type | Diameter class, in.[a] | Av. moist. % of green wt. | Av. density g./cc.[b] | Growth rate, rings/in. |
|---|---|---|---|---|
| Thinnings | 0.9–2.4 | 56.9 | 0.431 | 8.4 |
| Thinnings | 2.5–3.3 | 50.2 | 0.507 | |
| Whips | 1.0–2.4 | 53.9 | 0.455 | 13.0 |
| Whips | 2.5–3.5 | 45.6 | 0.537 | |
| Normal pulpwood[c] | 6–10 | 49.4 | 0.511 | 7.6 |

[a] Diameter measured inside bark.
[b] Density = g. ovendry weight per cc. green volume.
[c] Data from 28 lots of sample wood used in previous pulping experiments.

in. in length was cut at approximately breast height, and a similar sample was cut from the point at which the stem tapered to approximately 1 1/2 in. diameter. From each of the ten areas, five trees were also selected as being typical of the small trees normally left after a harvesting operation of the "clear-cut" type. These remaining stems are commonly referred to as "whips." Stem samples similar to those taken from the thinnings were also cut from these whip trees. Notation was made of the location and the type of stand from which the samples were taken, and the fresh samples were packaged with these notations in plastic bags in the field. The 20 wood specimens from each of the ten areas were then promptly forwarded to Savannah.

The stem samples were tested for size, density, moisture, age, growth rate, and bark content. Average test data are presented in Table I. It was readily apparent that the physical characteristics of the very small samples were different from those of the larger diameter pieces, and each of the wood types were further divided into two diameter classes. Reference to Table I shows that for both the thinnings and the whips, the stems of less than 2.5 in. diameter were characterized by higher moisture content and considerably lower dry density than the specimens in the 2.5 to 3.5-in. diameter class. The bark content of the combined thinnings and whips over 2.5 in, in diameter amounted to 18.3% of the initial rough green weight. It is estimated that the wood loss in debarking, chipping, and screening the small trees amounts to 5% of the initial wood weight. This means that, disregarding moisture losses during processing, it would require about 6450 lb. of rough, green, stems in the 2.5 to 3.5-in. class to produce 5000 lb. of bark-free chips.

The low density of the thinnings and whips in the smaller diameter classes obviously means that the pulp mill buying this type of wood under a system of relative solid wood volume measurement, such as chip volume, will receive less pulping material in a purchase unit of this wood than in a purchase unit of normal slash pine pulpwood. In the case of low density thinnings the volume unit of small stem wood may contain approximately 15% less pulping material than an equal-size volume unit of normal slash pine. No study of the stacking characteristics of this very small wood was included in the project reported here, but from the well-established relationship of solid volume to average stick diameter in larger wood, it can be safely concluded that a stacked cord of this wood will contain less wood than an equal rough volume of normal size pulpwood. It is estimated that, even after removal of the bark, a 128-cu. ft. rick of 1.0 to 2.5-in. slash pine stems will contain less wood than a cord of normal size rough pulpwood.

**Table II. Standard Cooking Conditions**

| | |
|---|---|
| Chip size distribution: | |
| Passing 1-in. screen; retained on 3/4 in., % | 25 |
| Passing 3/4-in. screen; retained on 1/2 in., % | 40 |
| Passing 1/2-in. screen; retained on 1/4 in., % | 35 |
| Cooking temp., °F | 344 |
| Time to max. temp., min. | 60 |
| Time at max. temp., min. | 80 |
| Time to blow pressure, min. | 10 |
| Blow pressure, p.s.i.g. | 70 |
| Sulfidity, %, active basis | 30.0 |
| Activity, % | 82.5 |
| Liquor to wood ratio[a] | 4.5:1 |

[a] Liquor includes moisture in wood.

**Table III. Physical Characteristics of Wood Samples for Experimental Pulping**

| Type | Diameter range, in. | Moist., % green wt. | Density, g./cc | Growth rate, rings/in. |
|---|---|---|---|---|
| Thinnings | 1.0–3.4 | 53.7 | 0.498 | 6.6 |
| Whips | 1.8–4.5 | 48.1 | 0.518 | 14.7 |
| Reference wood[a] | 6–10 | 49.4 | 0.511 | 7.6 |

[a] Same as in Table I.

It can also be seen that purchasing the small wood by weight at a constant price per unit of green weight is unreliable because of the high moisture content of the lower density wood. The average cord of round wood received by the Savannah mill from the coastal plain area has been found to yield approximately 2470 lb. of ovendry chips. At a moisture content of 56.9%, a bark content of 20% and a wood loss of 5% in processing, it will require 7540 lb. of the smallest thinnings to yield a cord-equivalent of chips on a dry weight basis. At a moisture content of 45.6%, a bark content of 15%, and a wood loss of 5%, it will require only 5690 lb. of the larger whips to yield a cord-equivalent of chips.

It is evident that under any of the common methods of purchase, the dry weight of wood received per unit of purchase will be extremely variable among the various types of small wood. This variability makes it imperative that small tree utilization projects be individually evaluated by the mills undertaking them.

## PULPING CHARACTERISTICS

Assistance was received from our Woodlands Division and Industrial Engineering Department in the selection and processing of small diameter samples for pulping in the pulping laboratory. It was believed that the physical characteristics of the thinnings which might give abnormal pulping results were the high percentage of wood formed during the first few years of stem growth and the corresponding low wood density. For this reason, care was exercised to obtain stems of above normal growth rate and early growth wood content for pulping laboratory use. It was also believed that slow growth rate and high density might be the most troublesome characteristics of the whips. Here also, care was taken to secure a sample for pulping in which these characteristics were more pronounced than in typical whip wood. It is reasonable to assume that if samples displaying extremes of these properties could be pulped satisfactorily, any wood with more normal characteristics could also be pulped satisfactorily.

The slash pine trees for the pulping laboratory sample were selected from two areas within 20 miles of Savannah, Ga. To produce the amount of chips required, it was necessary to obtain 15 trees of the thinnings type and five trees of the

**Table IV. Pulping Characteristics of Small Wood**

| Wood type | Number cooks[a] | NaOH, %[b] | Av. pulp permanganate no.[c] | Yield, % Total | Yield, % O.D.[d] wood Screened | Rejects, % total yield[e] |
|---|---|---|---|---|---|---|
| Thinnings | 3 | 12.0 | 29.1 | 48.3 | 45.2 | 6.4 |
| Whips | 3 | 11.3 | 28.9 | 49.1 | 46.6 | 5.1 |
| Reference data[f] | 13 | 11.2 | 29.4 | 48.2 | 45.8 | 5.0 |

[a] Includes only cooks in 28.0 to 30.0 permanganate no. range.
[b] As $Na_2O$, expressed as per cent of dry wood weight.
[c] TAPPI Standard T 214 m-53.
[d] O.D. = ovendry.
[e] Rejects removed by 0.010-in. cut flat screen.
[f] Results obtained from standard pulping laboratory cooks of the mill's normal pinewood supply.

Table V. Strength Characteristics of Small Wood Pulps

| Wood type | Permanganate no. | Strength of pulps at 700 ml. freeness[a,b] Burst | Tear | Tensile |
|---|---|---|---|---|
| Thinnings | 29.1 | 81 | 141 | 1087 |
| Whips | 28.9 | 91 | 158 | 1227 |
| Reference data | 29.4 | 82 | 147 | 1042 |

[a] Schopper-Riegler 2 g. freeness.
[b] TAPPI Standard strength factors.

whip type. All of these trees were manually debarked and were chipped in a sawmill chipper. It was noted that the quality of these chips was not as high as that of mill chips, nor as high as the quality of most of our purchased chips. The presence of an unusually high percentage of slivers in the chips may have been due to the slow, single stick feeding of the wood to the chipper, and it is possible that this difficulty would be partially overcome by faster feeding in a normal chipping operation.

The chips were screened on the laboratory chip screen and recombined in our standard laboratory proportions of size fractions shown in Table II. This was done to standardize the effect of chip size on pulping behavior for comparison of these experimental pulps with other experimental pulps made from normal pulpwood.

All of the experimental pulps of this series were cooked to permanganate numbers within the range of $29 \pm 1$, with permanganate number control being accomplished by varying the amount of chemical used. The other cooking conditions observed were those conditions adopted as standard conditions in our pulping laboratory for periodic evaluation of our normal wood supply. These standard conditions are listed in Table II. In the case of both the thinnings and the whips, three cooks were made in the desired permanganate number range.

In Table III are shown the physical characteristics of the wood obtained for the experimental pulping. It can be noted that in moisture content, density, and growth rate, the reference wood characteristics fell between those of the whip and thinnings samples.

Some of the pulping characteristics of the small wood are given in Table IV, with corresponding characteristics of 13 laboratory cooks of normal pine pulpwood cut from the same general area as the small wood. It can be seen that the low density thinnings required considerably more chemical than the normal wood in being cooked to only a slightly lower permanganate number. Although the total yield obtained from these two types was practically the same, the rejects from the thinnings were greater and the screened yield lower than from the normal wood. On the other hand, although chemical consumption and reject production were essentially the same for the high density whips and the normal wood, the total yield and screened yield obtained from the whips were slightly greater than from the normal wood. These differences in pulping characteristics are in general agreement with previous work done in our laboratory on the effects of density variation in southern pine on sulfate pulping.

The strength characteristics of the small wood pulps are given in Table V. The high tearing strength of the experimental pulp from the whips was typical of other high density wood samples pulped in our laboratory, but the higher bursting and tensile strengths of this pulp were unusual. The slow growth rate of this wood sample may have, in some way, been the cause of this strength characteristic. If this were the case, similar whips could be expected to yield equally high strength pulp, but it must be remembered that this sample was slower in growth than most of the stem samples. In other wood studies conducted at our Savannah mill, many sticks of regular pulpwood have been found to be lower in density than the average of the thinnings samples in the 2.5 to 3.3 in. diam. class. Similarly, many sticks have been found to be higher in density than the average of the whip samples in the larger diameter class. Since, in general, the small diameter wood responded to pulping in the same manner as normal size wood of this same density, it can be concluded that the use of chips cut from small pines would have about the same effect as using an equal quantity of regular pulpwood of slightly unusual density.

It is believed that the findings of the study reported here are adequate evidence that if small diameter slash pine trees from the coastal plain area of Georgia and South Carolina can be converted into chips of acceptable size, quality, and cleanliness, they can be utilized in the production of acceptable quality unbleached kraft pulp. This wood will exhibit certain physical characteristics different from those of normal size wood that should be carefully evaluated with regard to the basis on which this wood is to be bought or sold by the pulp company. The pulping characteristics are not greatly different from those of normal size wood of equal density, and especially when the relative amounts of the undersize wood to be used in mixture with normal wood are small, no special pulping provisions should be required.

The question regarding the prospects of developing economical methods of harvesting and processing the small stems remains incompletely answered and is receiving additional attention. Reports from other companies indicate that some attempts to salvage small stems are marginal in economy and other attempts have been abandoned because of definitely unfavorable costs. It can be readily appreciated that the handling of individual stems must be minimized and that bulk handling, either in stick or chip form, is essential. It is considered likely that, until radically new harvesting or processing methods are developed, the utilization of this wood will be economically justified only in those instances where a substantial dollar value can be placed on the benefit to the stand from which it is removed.

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# Sudbrook Pulp Mill, Description and Operation

L. DEWHIRST

A PULP MILL has been erected in Great Britian, a traditional pulp buying country, this fact has caused comment.

Our country is regarded as one having very small forestry reserves, this is true, but there is enough wood available for a small pulp mill, using homegrown hardwoods. It did require a great deal of courage to enter into the economics of building a pulp mill and it was due to Wiggins Teape & Co., Ltd., fine papermakers, that a decision to go ahead and build Sudbrook Pulp Mill was made. Remember there is no background of pulp manufacture in this country, and from top management to the shift worker, everything concerned with the pulp mill would be new. All would have to learn how to run the plant the hard way, but yet the mill is operating and producing a pulp which is used in all fine papers produced by Wiggins Teape.

The amount of wood available on a sustained basis is approximately between 80,000 and 90,000 tons per annum. The quality of wood is not as high as you in America expect and our specification is more liberal. To increase the output further, we shall look to waste wood utilization.

The percentage of conifers and broad leaved trees growing in the United Kingdom are 53 and 47 respectively but the output of the former in terms of tonnage is growing as newly planted forests come to maturity but it is with the latter percentage Sudbrook is concerned. These hardwood supplies are transformed into neutral sulfite semichemical bleached pulp, we prefer to miss out the "semichemical" for bleached pulp since we believe that it is a misnomer and we prefer to call our pulp *"neutral sulfite pulp"* and our trade name is "Gatecel."

L. DEWHIRST, Sudbrook Pulp Mill, Ltd., Sudbrook, England.

Wiggins Teape, for over 200 years, have marketed papers under the trade-mark of a medieval gate. These "Gateway" papers have a world-wide reputation. Therefore, we wished to carry on the tradition, and named our neutral sulfite pulp Gatecel.

What are the important requirements for siting a small nonintegrated pulp mill. We came to the following conclusions: proximity to supplies of raw materials, e.g., wood and chemicals; plentiful supply of good water; ease of effluent disposal; and proximity to paper mills.

If we divide England across the "waist," i.e., from Hull in the east to Liverpool in the west, south of this line is the area where hardwood growth predominates. This area can be narrowed down further because in the west is the ancient Royal Forest of Dean—once the private hunting grounds of the Kings of England, Charles I was the last to use it. This forest, though small now compared to its former size, was protected and developed into a hardwood forest—predominant species—oak, since this wood provided the British Navy with its famous wooden walls up to the end of the 19th century.

With the advent of iron, steel, and steam, the usefulness of these forests for shipbuilding deteriorated, and most hardwood was used for either pitprops or charcoal. This did not decimate the forest, but in many parts it became common land for grazing cattle and sheep. Consequently, young growth did suffer.

In later years two world wars took their toll of English woods because our mining industry normally obtains its pit props from Scandinavia and Canada, but during the wars the hardwood forests were cut to provide these. Now we have the real size of our largest hardwood forest, 25,000 acres. This forest does supply considerable tonnages and a site was sought within striking distance.

Water supply is always a problem but when our railways were constructed, South Wales a coal producing area required communication with other centers, therefore, a tunnel was projected under the River Severn. During this construction an underground stream was met, attempts were made to divert it, but these were unsuccessful and pumping had to be done. Since 1875 British Railways have pumped (using Cornish beam engines installed at that time) some 20 to 22 million gallons of water per day from the stream and tunnel back into the river itself. Of this total 10 to 12 million gallons is good clean water but with a hardness of some 300 p.p.m. as calcium carbonate. We use this latter water for producing Gatecel pulp.

By great chance the pumping station was sited on the edge of the river, which is tidal, in fact, the River Severn has a tide of 40 to 45 ft. at this point. Here then is the answer to effluent disposal. By running a discharge pipe out into the estuary, effluent disposal can be done with the greatest possible dilution effect.

Wiggins Teape for many years have been conscious of the value of hardwood, free draining pulps in all grades of paper. These small-fibered pulps have good formation properties and produce a good sheet with a minimum amount of beating. Therefore, the group decided that it should produce a bleached neutral sulfite pulp of a general character for use in their grades of paper. Wiggins Teape have 18 paper mills situated around Great Britain, but the bulk are to be found within 120 miles radius of Sudbrook. In order to obtain the best distribution of Gatecel, we decided that each mill should be allowed to develop the use of Gatecel in its own papers. This has proved eminently successful and all our mills were only too pleased to cooperate with us. In the early days of startup when the pulp produced was not good, they were anxious to encourage and not condemn us. Now Gatecel is found in all Wiggins Teape papers ranging from dry crepe tissue, banks, bonds, writing papers, greaseproof, glassine, vegetable parchment, duplicating papers, and it is now being used in the base paper for N.C.R.

Sudbrook is virtually the only site in Southern England which can accommodate a pulp mill.

Civil engineering work was commenced in October, 1956, erection of machinery October, 1957, and the first "batch" of pulp made in Spring, 1958.

I would like to break up the technical description of the process into (a) wood handling and wood preparation, (b) digestion and brown stock washing, (c) bleaching, (d) sheet forming and baling, (e) chemical preparation, and (f) services.

## WOOD HANDLING AND WOOD PREPARATION

All English homegrown hardwoods are processed but the supply is a random mixture and the predominent species are as follows:

| | |
|---|---|
| Oak | 30% |
| Birch | 15–20% |
| Beech | 15% |
| Ash | 10% |

The remaining 20 to 30% is alder, elm, chestnut, lime, willow, and poplar.

When we looked at the quality of English hardwoods, we decided that it would be preferable for us to buy by weight instead of by volume. We made this decision when it was not common practice in America to buy by weight. It required some courage on our part to go forward against the established wood-buying methods but we did go through with it. From a wood procurement angle this was the only way we could buy and now the suppliers are very happy with the arrangement.

The amounts of hardwood are limited and our specification in relation to curvature is not as strict as in American mills.

With this in mind we decided against using any friction type of barking equipment such as drum barkers and decided to use a single log barker. This could be a questionable decision but the machine we chose was a Cambio and we had trials made in Sweden on our English hardwood. We have found the machine to be light in construction particularly for the "hard" rough bark species such as alder (when dry). In order to obtain the best results we have placed two machines in series and have two production lines in order to maintain the output when one stream requires maintenance.

With such a variety of species we have given these machines a difficult task, which, in the main they have overcome. Our difficulties in this section are many, but our self-imposed wood length of 4 ft. has presented the greatest. This is the minimum length the Cambio will take and it requires a great deal of thought in feeding these short logs to the machine. We have solved this in conjunction with the manufacturers by placing paddle type diabolo rolls before and after the actual spiked feed rolls of the machine itself. These rolls have provided extra fulcrums for the logs passing through the machine. The five barking tools of the machine rotate at 300 r.p.m. while the logs are driven through at 100 f.p.m. linear speed.

We try to bark the wood as green as possible because some species, notably ash, which has a thin bark, on drying becomes almost impossible to debark. Other species, i.e., lime, elm, and chestnut have barks which are stringy in nature and are not successfully barked in the machine, but by passing through the second stage we usually obtain 100% bark removal. Other problems encountered using this barking machine have been barking tool design, profile of tip, hardening of tip, and general strength of the moving parts. With the maker's help a newly designed tool has been used and the results obtained have been successful.

After barking, logs are passed to the chipping machine which is a 10-knife Ottersland chipper with a disk diameter of 6 ft. The maximum log diameter which can be taken is 12 in. The chipper rotates at 500 r.p.m. using 350 hp. The chip size is $^1/_2$ in. and these are screened on a chip screen of

capacity 3200 cu. ft. of chips per hour. Chips are stored in a silo of three compartments, total capacity 350 tons. The wood preparation department is run on a three-shift basis and stops for planned checkups every Sunday.

## DIGESTION AND BROWN STOCK WASHING

The choice between a continuous or batch digester for a small production such as Sudbrook, i.e, 28,000 tons per annum is not an easy one to make. The trend of all industry is to continuous production 7 days per week, and this, together with capital cost, labor requirements, simplicity of layout, were the deciding factors in choosing the Kamyr continuous system. The difference in capital cost for a smaller unit and our present size was negligible, so we took a slightly larger size than we planned originally, and as yet we have not found the true output. We believe that we could produce 110 tons unbleached pulp per day and hence approximately 35,000 tons bleached pulp per annum.

The size of the digester is 8.5 ft. diam., 55 ft. high, capacity 3300 cu. ft. It is a mild steel vessel lined with stainless steel, Type 316. The questions which require answering are:

Does the system work for hardwood cooking by neutral sulfite method?
Is it simple to operate?
Is it economical?

We believe the answer is "yes" in all three cases.

In general we have had very little maintenance trouble except for usual ones concerned with pump packings now solved by application of high-pressure gland sealing water.

Our Kamyr system is essentially straightforward and it is probably best to describe each feature.

### *Chip Feed*

We have a small chip hopper above the conventional steaming vessel. This hopper has a capacity of 2 hr. production and is fed automatically from the chip silo. From the hopper we measure volumetrically the amount of chips through a star feeder, the speed of which can be regulated from the control panel. We have an integrating mechanism to give a total daily feed of chips but a further check is made by a continuous weightometer situated on the conveyor system which feeds the chip hopper. From the chip meter, chips are fed into a low-pressure feeder which divides the atmospheric pressure of the chip hopper from the low-pressure system of the steaming vessel. The steaming vessel is a horizontal cylindrical tube, containing a screw which feeds the chips to a chute down which they drop into the high-pressure feeder. This system is under 15 lb. steam pressure. The high-pressure feeder divides the high-pressure system of the digester from the low pressure of the steaming vessel.

Liquor from the top of the digester is passed to the suction of the top circulation pump and delivered from this pump through the high-pressure feeder back to the top of the digester. Chips fall down into the vertical pockets of the rotating feeder and are flushed to the top of the digester when the pockets are horizontal by the top circulation liquor flow. In the top of the digester liquor and chips enter a cylindrical screen through which a screw pushes the chips into the body of the digester. Liquor from the top circulation is drawn from behind this screen.

The chute above the high-pressure feeder also has a screen, and liquor is circulated through the screen and drains from the bottom of the high-pressure feeder to a further pump which completes the circulation back to the chip chute. This circulation flushes chips into the vertical empty pockets of the high-pressure feeder while top circulation flushes them into the digester when the pockets are horizontal.

### *Liquor Feed*

Cooking liquor is pumped to a constant head tank at a controlled flow, commensurate to the chip feed. From the constant head tank it is fed to a two-stage high-pressure pump which, in addition to pumping liquor to the digester, controls the operating pressure of the system. It is clear that the volume of cooking liquor going into the digester is probably insufficient to maintain a uniform pressure. The constant head tank has a level control device which ensures that makeup water is fed to the pump to maintain uniform digester pressure. We use cold water for this purpose. Any overflow from the chip chute circulation mentioned in the previous section, is also fed to the head tank and produces a further source of makeup water for the digester. The pressure control valve is on the delivery side of the high pressure pump, the impulse for the controller being taken from the top of the digester.

### *Heating System*

Liquor is taken from behind the screens situated approximately at the center of the digester, passed through a heat exchanger, and re-circulated into the body of the digester through a central tube.

To prevent plugging of the screens each screen is divided into two sections. Each section has a time cycle controller butterfly valve so the suction of the cooking circulation pump is taken from first one section and then the other section of the cooking screen. At Sudbrook we have two separate cooking systems, the top screens give a short impregnation time and hence a long cooking period while the bottom screens give us a long impregnation and shorter cooking. For the present throughput we are using the lower screens.

### *Extraction*

Liquor and chips pass forward to a strainer in which part of the liquor is withdrawn and re-circulated to the base of the digester, to help to flush out the down-flowing cooked chips.

In the strainer there is a paddle agitator which has a dual purpose: (1) the power taken by the agitator is proportional to the consistency and hence a control can be made over the consistency of the stock leaving the strainer, and (2) on one paddle arm we have built a scraper of stellite steel which acts as a wiper to keep the face of the blow-hole clean.

From the strainer the chips are expanded through a small orifice into the blow line. The size of the orifice is variable but for the present production we are using approximately 20 by 25 mm. The blow line is $1^1/_8$ in. diam. expanding to $2^1/_2$ in. diam. up to a small blow tank. Just before the blow tank we split the $2^1/_2$ in. line into a 2-in. T junction feeding diametrically opposite sides of the blow tank, each feed supplying chips to two Sprout Waldron refiners acting in parallel.

### *Operational Snags*

I am sure everybody is conversant with this normal Kamyr system and I would think that you are more interested in knowing what have been our operational snags, and how we have overcome them.

*Training.* As stated previously, all personnel had to be trained. The digester operators were specially chosen men and were trained by Kamyr engineers. After the Swedish engineers had left we had a period when the mill ran smoothly and our operators forgot basic training. It was only when the mill started going astray again that we had to re-train these men and now we are in a position to say that the operators run this continuous system smoothly and intelligently to produce a uniform pulp which in the time we have been producing and their initial inexperience is a tremendous achievement.

*Hard Water.* The process water we use comes from an underground stream. It has a high temporary hardness, in terms of calcium carbonate approximately 300 p.p.m. Optimistically, we thought we could get away with using this water in the process without treatment. We found that we

could not because the digester system is sensitive to scale formation. From our cooking liquor we get a precipitation of calcium sulfite; this forms a soft scale in all feed lines and control valves of the digester. This has given us the greatest amount of trouble because as the lines scale up it has been difficult to maintain uniform digester pressure, correct flow of cooking liquor and makeup water, and, the chip-chute screens, top screens of the digester, and the cooking screens became blocked. All this tended to make the operation of the digester very unstable giving the operators considerable difficulties but we continued to produce pulp under these circumstances.

We have had to shut down every 3 months to de-scale these lines, but now we have installed a lime soda water treatment plant to remove the calcium hardness and this has ensured much smoother operation of the digester.

*Chip Size.* We are convinced that a $^1/_2$-in. chip is correct for neutral sulfite pulping, and we ran into difficulty in keeping the two-stage, high-pressure pumps free of fines. We thought, at first, our chipper was giving us trouble, but we decided our chips were no worse or no better than anyone elses. The strainer at the top of the digester has 2-mm. wide slots and therefore fine chips which give a batch digester no trouble may pass through the slots. This means that they come into the suction side of the top circulation system. They are, therefore, circulated around through the high-pressure feeder and can enter the chip circulation system. Here again, in the chip chute, the screen slots are 2 mm. wide. From here, via the equilizing lines between the chip chute and the constant head tank these fines make their way into the suction side of the high-pressure pumps where they block the impellers. It would be wrong to say we have completely overcome this problem by installing larger impellers, i.e., impellers with larger eyes, through which fines will pass back to the digester. Unfortunately, they are only re-circulated into the digester behind the top screens, where they accumulate. The next thing we shall do is to cut down the size of the slots in the chip-chute screens and the top screen to $1^1/_4$ mm. This, we believe, will be the answer to the fines problem.

*"Banging."* "Banging" or bumping of the top circulation pipework is the worst operational feature of this type of continuous cooker. During cooking the wood acids formed liberate carbon dioxide from the buffer. At the top of the digester this gas may form a frothy liquor particularly if pressure conditions in the digester are unstable. If this occurs, the frothy liquor circulates round the top circulation system feeding chips through the high-pressure feeder, and a severe type of "water hammer" takes place.

Banging may be caused by a too high top circulation temperature together with low steam pressure in the chip chute and steaming vessel. Under these conditions, "flashing" of liquor may occur in the pockets of the high-pressure feeder.

Another cause is from the steaming vessel itself, chips passing through lose air which, if not vented continuously, will pass into the pockets of the high-pressure feeder with the chips.

These problems have been solved and banging kept under control.

(a) We have a continuous vent or bleed off from the top of the digester. In this line we have a sight glass so that the operator can see what is leaving the system and if he is letting too much liquor out with the gases.

(b) It is preferable to maintain a high top circulation temperature while having a good steam pressure in the steaming vessel. At Sudbrook these are 90 to 95°C. and 15 p.s.i.

(c) We have a continuous vent from the steaming vessel and keep a good steam supply into the vessel.

(d) Intelligent anticipation by the operators ensures that banging never starts.

*Makeup Water Usage.* A further operational feature of the system is to have as little steam consumption as possible, otherwise one of the economic advantages of the continuous system is lost. To do this it is essential to keep the top circulation temperatures as near 100°C. as possible. In our case we have no re-use of black liquor; all our makeup water is cold. This is fed straight to the top of the digester, and means that we could operate with a low temperature of say 70 to 75°C., but this, although it helps with the banging problems, certainly does not help the steam consumption. The answer is to have as little makeup water as possible and this can be controlled by an efficient bottom circulation. The more liquor that can be re-circulated around the bottom of the digester, the less you have to put in at the top to maintain the hydraulic pressure. Consequently, a higher top temperature and a more uniform cooking temperature will result. For some time we were unable to operate the strainer at the bottom of the digester efficiently, but we have cured the problem by certain modifications within the strainer itself.

We inject cold water to the base of the digester in addition to the bottom circulation. This means that we cool pulp at the bottom of the digester from 165 to 125°C. Cold water addition to the bottom helps to maintain the hydraulic pressure and decreases the cold water input to the top with a result that our steam consumption has dropped considerably.

You may think that it is a disadvantage to have a small blow line and that it would block. We have had very few blockages indeed during normal operation and the smaller the blow line the easier it is to keep the liquor back to the bottom circulation, thereby helping to keep the steam consumption low.

*"Hanging."* If the chip column does not uniformly move down to the digester, i.e., "hanging" occurs, then the operational stability of the digester is upset. Hanging can occur for various reasons.

*Intermittent chip feed:* This is bad operation and should be put right by carefully checking with the operators to see that they understand what is happening in the digester. Uniform chip feed is the chief preventative against hanging taking place.

*Insufficient volume on the cooking circulation:* This will mean that the down thrust on the chip column via the liquor return to the digester from the heat exchanger is insufficient to push the cooked chips to the bottom of the digester. We suffered from this for some time and there were two reasons for it: (1) the cooking screens became dirty and scaled up, and (2) the end of the return central pipe in the digester was too near the suction points on the top half of the screen in use.

We shortened this pipe by some 4 ft. and the thrust downward greatly improved. Cleaning of the screens can be improved by better operation and dirty screens can occur if the digester is shut down and not re-started correctly. The best way to re-start after a small shutdown is to start feeding chips in and discharge at the same time without starting the cooking circulation for at least 10 min. This means that the chips themselves will clean the screens and for 10-min. cooking takes place on the original heat inside the digester, but, as soon as the cooking circulation is started, temperature is quickly restored.

In a short shutdown temperature loss is probably of the order of 5 to 10° provided digester pressure is maintained.

*Mechanical Snags.* Apart from initial trouble with the high-pressure pumps, all moving equipment has been more or less trouble-free but the banging which we have experienced has caused us a certain amount of trouble with pipework and the instruments. Apart from this, it is fair to say that the system has operated extremely well considering this pulp mill is the only one in the United Kingdom, and that all the operators had never been inside one before.

### *Operating Details*

The operating details for approximately 65 tons per day unbleached output are shown in Table I.

**Table I. Operational Details for Approximately 65 Tons per Day Unbleached Output**

| | |
|---|---|
| 1. Steam pressure to heat exchangers | 200 p.s.i.g. |
| 2. Chip feed to digester | 8 1/2 r.p.m., 160 lb. airdry wood per min. |
| 3. Strength of liquor (storage tanks) | 125 g.p.l. sodium sulfite. |
| Amount of liquor | 24 g.p.m. equivalent to 17% sodium sulfite on airdry woods<br>4% bicarbonate on airdry woods |
| 4. pH at top of digester, and concentration of liquor | 9.2<br>51 g.p.l. |
| 5. Makeup water | 15 to 18 g.p.m. |
| 6. Top circulation flow | 1000 g.p.m. |
| 7. Liquor to wood ratio | 3.3 to 3.5:1 |
| 8. Top temperature | 90°C. |
| 9. Digester pressure | 175 p.s.i.g. |
| 10. Cooking temperature | 168° to 170°C. |
| 11. Impregnation time | 2 hr., approx. |
| 12. Cooking time using lower screens | 3 to 3 1/2 hr. |
| 13. Temperature after heat exchangers | 173°C. |
| 14. Cooking circulation flow | 800 g.p.m. |
| 15. Temperature of bottom circulation | 125°C. |
| 16. Amount of cold water injection | 10 g.p.m. |
| 17. Bottom circulation | 10 to 15 g.p.m. |
| 18. Residual sodium sulfite | 6 to 8 g.p.l. |
| 19. pH bottom circulation | 7.5 to 8.0 |
| 20. Yield of unbleached pulp approx. | 70 to 72% |

All gallons are Imperial.

### *Brown Stock Washing and Screening*

The refined stock is passed down to a small chest, diluted to 1%, and pumped to the first brown stock washer. The pulp is washed free of black liquor diluted to 0.75% on the outgoing side of the filter, and drops into a small buffer chest. From here we pump it up to 12-in. cyclones, four in the first stage and one in the second stage. The accepts from the 12-in. cyclones pass to selectifiers with 42-mil perforations in the baskets and the accepts from there go to a further brown stock washer which really acts as a concentrator passing the stock at 4 to 5% into the unbleached storage chests. Rejects from the second stage 12-in. cyclones and from the selectifiers are fed to a small chest from where they go back to the Sprout Waldron refiners.

**Table II. Bleaching Plant**

| | |
|---|---|
| **Chlorine Stage** | |
| 3.2% consistency | |
| Time of retention | 1 1/4 hr. |
| Temperature | 15°C. |
| Amount of chlorine added | 17 to 18% on the unbleached flow |
| **Alkali Extraction** | |
| 14% consistency | |
| Time of retention | 2 1/2 hr. |
| Temperature | 40°C. |
| Caustic soda | 7% on the unbleached flow |
| pH entering tower | 10.5 |
| pH inlet to washer | 8.0 to 8.5 |
| **Hypochlorite Stage** | |
| 8% consistency | |
| Time of retention | 5 hr. |
| Temperature | 35°C. |
| Caustic soda | 0.5 to 0.75% on the unbleached flow |
| Calcium hypochlorite as available chlorine | 1 1/2 to 2% on the unbleached flow |
| pH bottom of tower | 10.4 |
| pH leaving tower | 9.5 |
| Final brightness | 86 to 87° G.E. |

## BLEACHING PLANT

This is a conventional 3-stage bleaching process using chlorine, alkali extraction and, calcium hypochlorite. The details of the bleaching process are described in Table II.

### *Chlorine Stage*

Stock is measured from the unbleached chests using a magnetic flow meter and a closed system "pressure" type consistency regulator. Chlorine is fed to a premixer approximately 5 min. retention time before the base of the main tower. At the bottom of the tower is a second "mixer" to ensure uniform flow up the tower.

The tower is mild steel, rubber lined. At the top of the tower we have a scraper and a dilution spray ring which directs the pulp into a launder before dropping down to the first bleached washer inlet. We control the level in the launder to prevent a vortex occurring in the down pipe thereby ensuring no aeration of the stock.

The ingoing consistency to the filter is approximately 1 1/2%, and the outgoing 14 to 15%. Hot water sprays are used and the pH of the outgoing stock is approximately 2.0.

### *Alkali Extraction and Hypochlorite Treatment*

Caustic soda is added after the chlorine washer and the alkaline pulp is screw fed at the high consistency to the top of a small down-flow tower. Once again the tower is rubber-lined, mild steel, but the transporter screws are in stainless steel. At the bottom of the tower we have a dilution ring and mixer so that the stock is uniformly diluted before it is pumped to the caustic soda washer. We re-circulate the backwater to the dilution ring in the caustic tower and this we believe gives a bad washing effect and we intend to alter this system so that we dilute with fresh water. The ingoing consistency to the washer is approximately 1 1/2% and the outgoing consistency after using hot water sprays is approximately 15%. The stock is diluted on the mixing screw before passing to a horizontal mounted centrifugal pump which delivers stock at 8% into the hypochlorite tower. Calcium hypochlorite and caustic soda solution are added to the stock on the mixing screw before the pump.

The hypochlorite tower is rubber-lined mild steel, the stock at the top is diluted and removed by means of a scraper into a launder. The diluted stock passes down to a small chest where further dilution to 0.75% consistency is made. This diluted stock is pumped through a 3-stage 6-in. cyclone installation having 24, 4, and 2 cyclones respectively, this installation will be increased to 30, 6, and 2 to ensure good cleaning at higher throughput.

Accepted stock from the first stage is passed to a dewatering drum and then to a filter for washing.

The size of the washers is 7.5 ft. diam. by 7.5 ft. long giving a surface area of 178 sq. ft. For brown stock washing we expect to achieve a loading of 0.65 ton per sq. ft. per day. On the bleached washers we expect to get 0.55 ton per sq. ft. per day. The washers are Kamyr M.54 with floor level suction and work reasonably well except for the pick-off of the web from the drum. We have installed an air discharge to bring the web off the drum but are not yet satisfied with this and hope to improve on it in the near future.

Our caustic soda consumption for the alkali extraction stage is very high. We have made several tests in the laboratory which have led us to the conclusion that further washing of the chlorinated stock is necessary in order to reduce this. We had the foresight in designing the mill to leave space for an extra chlorine washer and an extra hypochlorite washer if required. We are now using the first space and we are installing two filters in series after the chlorination stage. This we believe will bring our alkali consumption down to something like 3% on the unbleached flow.

## SHEET FORMING AND BALING

We have already discussed the reasons why the mill was not integrated, therefore we had to produce our pulp in a condition for shipment, we had to decide whether we should dry the pulp to the normal 90% or whether we should dry it to 50% and transport a certain amount of water. We chose the latter method for the following reasons:

(a) We calculated the steam requirements, and the capital cost of drying equipment to ensure 90% dry pulp. We offset this against the transport costs of transporting the 50% dry pulp to the paper mills which we were supplying. We found that we broke even by transporting 50% dry pulp.

(b) From the paper mills' point of view our neutral sulfite pulp is very easy to disintegrate particularly in the 50% dry condition. We had tried previously to disintegrate almost dry neutral sulfite pulp and we found it to be a difficult proposition. Therefore, we believe that our decision to make 50% dry pulp was correct even if we ignored point (a) above. Our paper mills prefer Gatecel because of its ease of disintegration and because we can supply pulp to them by road which they can take straight on to the beater floors and hence straight to the machine. This means that we carry a stock of pulp at Sudbrook and our paper mills draw on us when and how they like.

The washed pulp from the bleaching plant is diluted to approximately 4% and passed into two small stock chests, from which it is pumped up to the headbox of a Kamyr uptaking machine. On the way consistency and quantity are measured by means of the closed system pressure type consistency controller and a magnetic flow meter, respectively.

The first stage of the Kamyr wet machine is a vacuum mold drum with two pneumatic press rolls. The pulp web is couched off the drum at approximately 27% dryness to the first press rolls. Dryness is increased to 37% after pressing and the web is passed around a large M.G. cylinder so that the temperature of the web is raised to help the efficiency of the second press rolls which follow the cylinder. After these press rolls, pulp dryness is between 48 and 50%. From the second press rolls the pulp sheet drops down 8 ft. and then passes round a lead roll into the horizontal plane. In the horizontal plane three slitter knives divide the sheet up into four equal sections, each section passes around a jockey roll at an angle of 45°. All four sheets then lie on top of each other and pass down to two rotating fly knives which cut the sheet to the required length. The cut sheets are passed on to an accelerator conveyor which speeds them to a layboy to form a bale. From the layboy, bales go to a press and then on to a wiring station where the wrapping paper and baling wires are placed on before storage and shipment.

**Table III. Labor Requirements**

Pulp Chemicals and Steam

We have tried to keep this as little as possible and our requirements are as follows:

| | |
|---|---|
| Chemical production, including water treatment | 2 men |
| Boiler house, and bark incinerator boiler | 2 men |
| Digester section | 1 man |
| Refiners and brown stock washing, also siding digester man on startups and shutdowns | 1 man |
| Bleaching plant and Kamyr uptaking machine down to baling press | 3 men |
| Baling press and fork lift truck driver taking bales to pulp storage | 4 men |
| Shift tester | 1 man |
| Shift supervisor | 1 man |

Woodyard

Shiftwork.

| | |
|---|---|
| Barking and chipping | 3 men |
| Loading, including crane driver | 4 men |
| Chargehand | 1 man |

Day work.

| | |
|---|---|
| Pulp despatch, shunting and general | 10 men |
| Yard labor | 20 men |

This is the complement of staff for production of pulp from the chip silo onward, and we have four shift teams working 24 hr., 7 days per week.

Our engineering services comprise six fitters, three electricians, two instrument mechanics, one pipe fitter, and a welder, plus mates.

In the laboratory we have a chief chemist, a quality control chemist, and seven assistants.

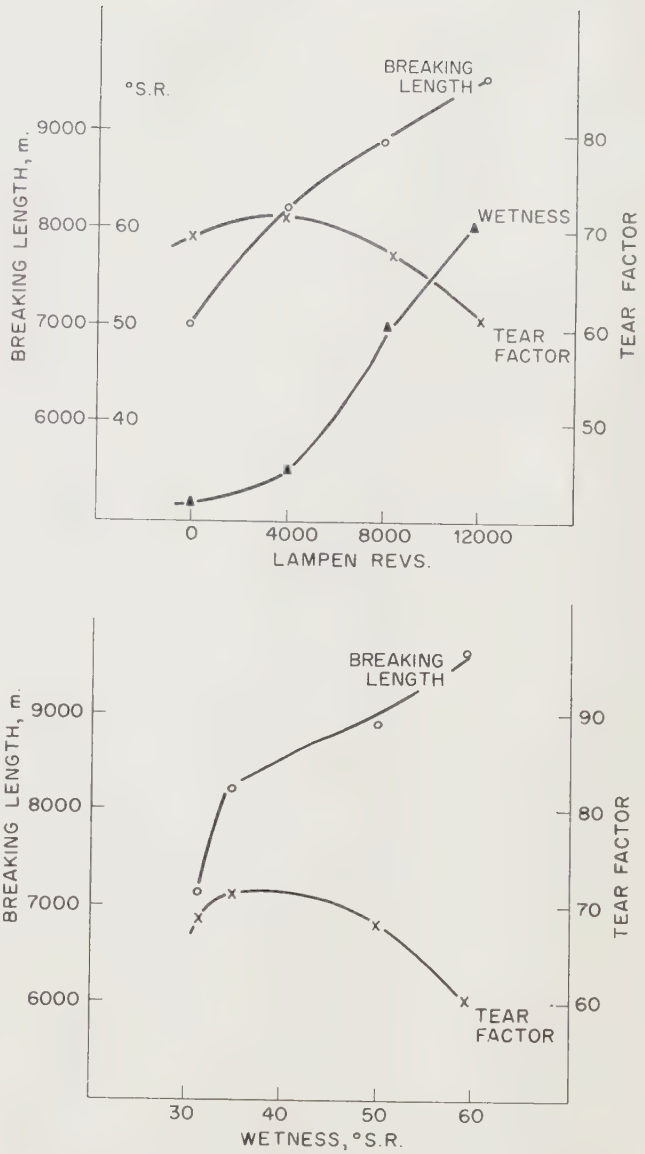


*Fig. 1. Evaluation of Gatecel bleached neutral sulfite*

## CHEMICAL PREPARATION

All our chemical preparations are extremely simple.

*Cooking Liquor.* We buy anhydrous sodium sulfite as a by-product from the phenol industry. The product is approximately 95% pure and we dissolve this up with sodium carbonate in a batch tank and pump into storage tanks before use in the digester section.

*Caustic Soda.* Caustic soda we buy as a 46% solution and we dilute batchwise to 10% for use in the bleaching plant.

*Chlorine.* We have no liquid chlorine storage tanks. We discharge straight from rail tank cars to an evaporator from which gas is measured to the bleaching process.

*Calcium Hypochlorite.* We buy hydrated lime, slurry it up, and chlorinate it as a batch process.

## SERVICES

These again are very simple. We get our water from an

**Table IV. Routine Test Data**

Percentage Chemicals Based Upon Unbleached Pulp.

| Roe[a] no. | °S.-R. unbl. | $Cl_2$, % | Residual $Cl_2$, % | pH $Cl_2$ filter | NaOH, % | pH, in. | °C. | Hypochlorite, % | pH, in. | °C. | Residual $Cl_2$, % | G.E. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 28th June | | | | | | | |
| 16.0 | ... | 19 | 0.24 | ... | 5.9 | 10.7 | 36 | 3.2 | 10.6 | 33 | ... | 89 |
| 13.6 | 16½ | 17½ | 0.18 | ... | 6.8 | 11.0 | 26 | 3.2 | 10.6 | 36 | 0.90 | 89 |
| 16.1 | ... | 19 | 0.23 | ... | 6.3 | 11.0 | 28 | 3.1 | 10.5 | 36 | ... | 90 |
| 15.8 | 16½ | ... | ... | ... | 6.8 | 11.0 | 31 | 3.1 | 10.7 | 30 | 0.32 | 89 |
| 15.6 | 16 | 19 | 0.73 | ... | 6.0 | 10.8 | 30 | 3.1 | 10.9 | 32 | ... | 90 |
| 15.6 | 17 | 19 | ... | ... | 6.0 | 11.7 | 31 | 3.0 | 10.8 | 35 | 0.11 | 90 |
| 15.4 | ... | 19 | 0.80 | ... | 5.6 | 11.4 | 30 | 3.0 | 10.5 | 35 | ... | 88 |
| 15.5 | 17½ | 19 | 1.4 | ... | 5.3 | 10.5 | 30 | 3.0 | 10.4 | 34 | 0.50 | 88 |
| 15.2 | ... | 17½ | 0.51 | ... | 5.6 | 11.1 | 30 | 3.0 | 10.7 | 34 | ... | 89 |
| | | | | | 29th June | | | | | | | |
| 15.6 | 16½ | 17½ | 0.29 | ... | 5.6 | 10.5 | 34 | 3.0 | 10.4 | 34 | ... | 89 |
| 15.8 | ... | 18 | 0.85 | ... | 5.6 | 10.9 | 33 | 2.6 | 10.5 | 25 | ... | 91 |
| 15.2 | 16 | 17½ | 1.4 | ... | 5.6 | 10.1 | 33 | 2.6 | 10.6 | 35 | 0.37 | 91 |
| 15.2 | ... | 17 | 0.70 | ... | 5.9 | 11.1 | 30 | 2.8 | 10.6 | 34 | ... | 89 |
| 15.2 | 16 | 17 | 0.60 | ... | 6.1 | 10.9 | 30 | 2.8 | 10.6 | 38 | 0.22 | 91 |
| 14.5 | ... | 17 | ... | 2.0 | 6.0 | 10.8 | 30 | 2.8 | 10.6 | 38 | ... | 90 |
| 14.4 | 16½ | 17 | 0.67 | 1.9 | 6.0 | 10.9 | 32 | 2.8 | 10.6 | 36 | 0.55 | 89 |
| 14.5 | 17 | 17 | 0.67 | ... | 6.0 | 10.8 | 32 | 2.8 | 10.3 | 35 | ... | .. |
| 15.4 | 16½ | 17½ | 0.37 | ... | 6.0 | 10.9 | 35 | 2.8 | 10.5 | 36 | 0.35 | 90 |
| 15.2 | ... | 17½ | 0.44 | ... | 6.0 | 11.3 | 35 | 2.8 | 10.3 | 36 | ... | 91 |
| 15.1 | 16½ | 17½ | 0.62 | ... | 6.0 | 11.5 | 35 | ... | ... | ... | 0.47 | 90 |
| 15.2 | ... | 17½ | ... | ... | 6.0 | 11.5 | 35 | 2.9 | 10.7 | 37 | ... | 91 |
| | | | | | 30th June | | | | | | | |
| 14.7 | 16 | 17½ | 0.54 | ... | 6.0 | 10.6 | 37 | 2.9 | 10.2 | 37 | 0.40 | 90 |
| 14.9 | 17 | 17½ | ... | ... | 6.0 | 11.1 | 32 | 2.9 | 10.5 | 36 | ... | 90 |
| 15.3 | ... | ... | ... | ... | 5.9 | 10.9 | 34 | 2.9 | 10.4 | 37 | ... | 91 |
| 14.7 | 15½ | 17½ | 0.20 | ... | 6.5 | 10.9 | 33 | 2.9 | 10.4 | 35 | 0.41 | 90 |
| 14.0 | ... | 17½ | 0.50 | ... | 6.5 | 11.1 | 33 | 2.9 | 10.6 | 37 | ... | 90 |
| 13.9 | 17 | 17 | 0.37 | ... | 6.0 | 11.1 | 34 | 2.9 | 10.6 | 37 | 0.62 | 90 |
| 13.7 | 17 | 17 | ... | ... | 5.7 | 10.4 | 33 | 2.9 | 10.4 | 35 | ... | 91 |
| 13.7 | 16 | 17 | 0.82 | ... | 6.0 | 10.9 | 35 | 2.9 | 10.7 | 35 | 0.93 | 91 |
| 14.1 | ... | 18 | 0.56 | ... | 6.0 | 11.5 | 35 | 2.9 | 10.7 | 35 | ... | 90 |
| 14.7 | 15½ | 17 | 0.43 | ... | 6.0 | 10.9 | 35 | 2.9 | 10.2 | 34 | ... | 90 |
| 14.6 | ... | 17 | ... | 2.1 | 6.0 | 10.4 | 33 | 2.6 | 10.8 | 37 | ... | .. |
| | | | | | 1st July | | | | | | | |
| 14.8 | 15 | 18 | 0.47 | 2.1 | 6.5 | 10.3 | 34 | 2.6 | 10.3 | 38 | ... | 90 |
| 15.0 | 16 | 18 | 0.54 | 2.1 | 6.8 | 11.2 | 34 | 2.6 | 10.7 | 37 | 0.67 | 91 |
| 14.6 | ... | 18 | 0.54 | 2.0 | 6.8 | 10.8 | 36 | 2.6 | 10.8 | 35 | ... | 89 |
| 15.1 | ... | 18 | 0.18 | 2.1 | 6.5 | 11.4 | 37 | 2.6 | 10.6 | 33 | ... | 89 |
| 16.8 | 15 | 18½ | 0.90 | 2.1 | 5.7 | 10.6 | 35 | 2.6 | 10.6 | 35 | ... | 92 |
| 14.5 | ... | 18 | 1.2 | ... | 6.0 | 10.9 | 34 | 2.6 | 10.6 | 34 | 0.80 | 90 |
| 15.1 | 15 | 17½ | 0.47 | ... | 6.5 | 10.8 | 34 | 2.6 | 10.7 | 34 | ... | 90 |
| 15.2 | ... | 17½ | 0.55 | 2.3 | 6.5 | 11.4 | 33 | 2.6 | 10.5 | 34 | ... | 91 |
| 14.9 | 15 | 17½ | ... | ... | 6.2 | 11.0 | 35 | 2.6 | 10.7 | 34 | ... | 90 |
| 14.7 | ... | 17 | 0.83 | 2.5 | 6.2 | 11.0 | 35 | 2.6 | 10.7 | 36 | ... | ... |
| 14.9 | 14 | 17½ | 0.73 | ... | 6.2 | 11.0 | 35 | 2.6 | 10.6 | 32 | ... | ... |
| 15.0 | ... | 17 | 0.43 | ... | 6.1 | 11.3 | 37 | 2.6 | 10.2 | 36 | ... | ... |

[a] Roe no. taken ever 2 hr. Other tests correspond to this–allowances being made for retention times. Percentage chemicals based upon unbleached pulp.

underground stream and pump it approximately a quarter of a mile into the mill. As stated previously the water is fairly hard and this has caused us some considerable trouble in the digester section so now we have a lime soda water treatment plant for that part of the water which goes into the digester section.

*Steam.* We have two Lancashire boilers having a total generating capacity of 25,000 lb. of steam per hour at 200 p.s.i. We burn our bark to produce approximately 4000–5000 lb. of steam per hour at 25 p.s.i. from which we produce all our hot water requirements.

*Electricity.* We take from the National grid at 11 000 v. and transform it down to 415 v. for use on the mill.

Table III shows labor requirements.

This paper has been designed to try to give you the story of Sudbrook Pulp Mill up to the present time. You will see from the attached pulp evaluation sheet a typical description of Gatecel pulp. We are not completely happy that our product is always uniform and up to the present we have aimed for two main characteristics: (a) uniform brightness at a minimum of 85° G.E. and (b) pulp which has a very small dirt count.

If we have been able to maintain these two qualities, our paper mills have been able to use the pulp.

We are now in control of these qualities and turning our attention to operating the plant so as to give us uniform physical characteristics for the final pulp. We are aiming for a breaking length of approximately 9500 m. at a wetness of 35°S.-R., i.e., approximately 300 ml. Canadian Standard freeness (Fig. 1).

Table IV shows a few days' operation from which the uniformity of production can be judged.

Table V shows a pulp evaluation of Gatecel.

## PROBLEMS

The general problems we have met during the manufacture are really those associated with an endeavor to make a completely continuous mill from the logs being fed to the barking machine to the pulp bales going to the paper mill.

We have very little storage capacity at any stage with the possible exception of the chip silo, where we have two days' supply but apart from this, unbleached and bleached storage are an hour to two hours' capacity only. Therefore, everything has to run uniformly from the Kamyr digester to the

Table V. Physical and Chemical Analysis

Bleached Gatecel

| | June | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *17* | *18* | *21* | *22* | *23* | *24* | *25* | *26* | *27* | *28* | *29* | *30* | *July 1* |
| G.E. brightness | 88 | 89 | 89 | 88 | 90 | 89 | 88 | 89 | ... | 89 | 90 | 90 | 90 |
| Unbeaten, °S.-R. | 31 | 34 | 31½ | 32 | 31½ | 32½ | 30 | 30 | | 31 | 30 | 28 | 30 |
| Breaking length, m. | 6550 | 8000 | 7500 | 6000 | 7000 | 7950 | 6100 | 6350 | | 7050 | 7050 | 6650 | 7150 |
| Tear factor | ... | 74 | ... | 75 | 69 | ... | ... | ... | ... | 68½ | ... | 76 | ... |
| Beaten to 35°S.-R. | ... | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| Breaking length, m. | 7950 | 8500 | 8700 | 8150 | 8200 | 8850 | ... | ... | ... | 7600 | 8400 | 8600 | 8400 |
| Tear factor | ... | 77 | ... | 84 | 71 | ... | ... | ... | ... | 73 | ... | 90 | ... |
| Alkali solubility | | | | | | | | | | | | | |
| $R_{10}$ | 79.9 | 82.5 | 78.0 | ... | 77.0 | ... | 78.5 | ... | 79.0 | 77.2 | ... | 78.4 | 78.0 |
| $R_{18}$ | 85.2 | 85.7 | 82.2 | ... | 82.8 | ... | 82.7 | ... | 82.3 | 83.6 | ... | 83.4 | 81.2 |
| Pentosan, % | ... | 20.2 | 20.5 | ... | 20.5 | ... | ... | ... | ... | 23.2 | ... | 24.9 | ... |
| Resin, % | 0.22 | 0.33 | 0.12 | ... | 0.38 | ... | 0.20 | ... | 0.14 | 0.19 | ... | 0.09 | 0.10 |

baling press conveyor and any small stoppages anywhere create down time for the whole mill. Most of our problems have been associated in getting the new equipment into full operation while, at the same time, trying to train completely "green" operators in the intricacies of a completely continuous process.

The final output of the mill will be something like 28,000 tons of pulp per year. At the moment we have not found where our bottlenecks are likely to be, and as long as the wood supply is sustained we believe that we can make between 75 and 85 tons of pulp per day without much trouble. However, it may take us some time to reach that output, but at the moment our production is 60 to 65 tons per day. The greatest enemy we have is a stoppage and therefore down time; we are not free of this bogy, but as the engineering staff gain more experience the stoppages become shorter and less frequent.

Before I close this paper I would like to make one point very clear. We believe it would have been impossible to have built Sudbrook without the cooperation of you people in America and our many Swedish friends. For example, on many occasions, I have written to Bob Collins who has restored our confidence in what we are doing by giving us the benefit of his great experience. Many other American mills have also answered our letters and queries so that we have been able to piece together information which has helped us to build and operate the mill. Our friends in Sweden, particularly within the Kamyr Organization and the Billeruds Group, have given us a great deal of cooperation and help and without them we certainly could not have had the courage to start and to keep going. You will, therefore, realize that Sudbrook, in many ways, has been an international project and all our personnel who have traveled in order to obtain information for Sudbrook are very grateful for the cooperation received and, in particular, I myself would like to make these thanks public through this paper. I also want to express my thanks to T. H. Frankel, Technical Manager, and the Directors of Wiggins Teape whose co-operation and permission have made this paper possible.

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**Eleventh Testing Conference**

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**Grand Rapids, Mich.**

**Sept. 27–29, 1960**

# Current Trends in Continuous Causticizing Practice

**W. CHRISTIANI, D. C. GILLESPIE, and R. P. LOGAN**

The major factors governing the design and operations of a continuous recausticizing system were first presented by Clemens (*1*) in 1947. The main functions of a recausticizing plant as set forth at that time may be summarized today as follows:

1. To convert as much as possible of the recovered sodium carbonate to sodium hydroxide.
2. To produce a suitably clarified white liquor of the desired concentration.
3. To separate, wash, and dewater the lime mud to prepare it for calcination.
4. To clarify the green liquor prior to recausticizing and to wash and thicken the resulting dregs.

Although the functions of a caustic plant have changed little in the past 12 years, a considerable number of improvements in operating practice, equipment design, and plant design have been made. In many cases, these innovations were initiated by pulp mill people and implemented by equipment manufacturers and engineering contractors. The purpose of this paper is to chart the progress made during the last twelve years in U. S. kraft mills, and to indicate current trends in continuous causticizing practice.

## TYPICAL MODERN FLOWSHEET

In the modern kraft caustic plant the basic liquor relationships remain the same—namely, the green liquor volume is normally 125%, and the wash water volume is usually 115% of the volume of white liquor. With the advent of kiln gas scrubbers and modified dregs washing, however, the distribution of the wash water throughout the system has changed somewhat. In a balanced system the total amount of wash water that can be added (which is called the "available" wash water) is restricted to the volume of the white liquor produced, plus the volume of water which leaves the system with the washed dregs and the filter cake. Water used for sprays and scrubbers in lime dust recovery systems, therefore, must be used in the mud washing system before being sent to the smelt dissolver. Also increased washing efficiency in the dregs washer may be attained by using a larger proportion of the available wash water (say, 30%) to recover soda from dregs before sending the same water on to wash lime mud. (A soda analysis of the dregs washer overflow determines whether this water should enter the mud system in the first or second stage washing.)

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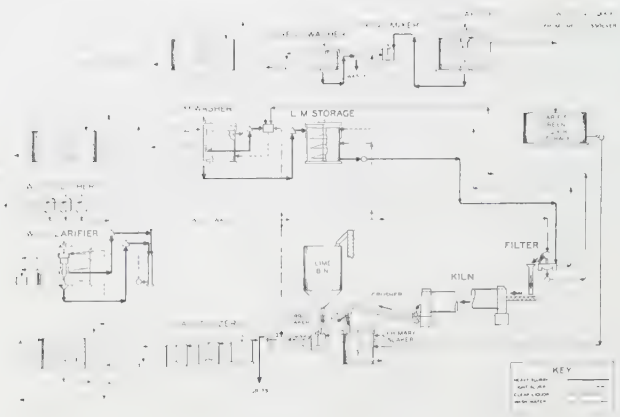


*Fig. 1. The Dorr continuous recausticizing system*

In Fig. 1 is shown a typical modern flowsheet designed to produce a highly polished white cooking liquor of uniform quality. The unit operations involved are discussed in detail below.

## GREEN LIQUOR CLARIFICATION

During the past 12 years several important changes have occurred in this operation. Concerning the raw green liquor feed, increased efficiency of modern recovery furnaces has meant lower dregs loadings in the clarifier. Newer plants now find the insoluble solids loading in the 6 to 12 lb. per ton of pulp range rather than the 10- to 15-lb average previously noted. In the area of equipment design, Gery (*2*) reported in 1954 on new, more efficient units with deep feedwells which made possible a three- to fourfold increase in design overflow rates, and at the same time lowered the initial equipment investment through a reduction in the number of compartments. A further increase in clarification efficiency has been made in the past 2 years through the introduction of a novel feedwell (termed the Type FF) which utilizes opposing feed streams to convert the inlet velocity head to the useful work of promoting flocculation of the fine solids (*3*).

The importance of this clarification step is sometimes minimized by plant personnel, especially in plants where rapid expansions have outstripped the clarifier capacity, and dirty overflows are the rule rather than the exception. A recent study of two causticizing systems by Rothrock (*4*) indicates some carryover of dregs into the slaking system does not seem to affect the clarity of the white liquor; however, higher causticizing efficiencies and lime availabilities were noted in the conventional system *with* green liquor clarification and two-stage mud washing as compared to the system operating *without* green liquor clarification and with one-stage mud washing.

Other studies indicate that a varying load of dregs to the slaking system may be responsible at least in part for operation variations in the mud dewatering step.

## DREGS WASHING

Increased soda recovery from green liquor dregs resulted when dregs washer specifications were revised from tray to unit compartment design in 1954 (*2*). This simplified unit has proved popular with the operators since it has eliminated overflow sleeve adjustments and minimized line scaling problems.

Helping to increase the washing efficiency of the single-stage unit is the dregs mixer ahead of the dregs washer. This unit insures thorough mixing of wash water and thickened dregs from the clarifier. To assist further in the soda recovery, several recent mills are designed to send up to 30% of the available wash water to the dregs washer before using it to wash lime mud.

A time-actuated diaphragm pump on the clarifier is used successfully in a number of mills to approach continuous dregs washing. Wash water flow to the dregs mixer is continuous but dregs are pumped to the mixer only 2 or 3 min. per 15-min. cycle, the time interval being set by experience. Small basket-type screens, along with improved recovery furnace operation, seem to have eliminated the occasional pumping problem caused by tramp oversize material in the raw green liquor.

Disposal of the dregs is usually with the plant wastes although a number of mills have had to use alternate means during difficult disposal periods. Parkinson (*5*) reported on successful burning of dregs in the kiln with the lime mud, and others have resorted to filtering and hauling.

## SLAKING AND CAUSTICIZING

One of the major changes in the recausticizing flowsheet over the past twelve years has been in the area of hot lime handling. A report (*6*) published in 1953 described a system of two-stage slaking which utilizes a large primary slaker between the kiln and the slaker-classifier. The system eliminated the need for a green liquor heater, hot lime elevator, reburned lime bin, and chain feeder, substituting for them an inclined apron or pan conveyor, the primary slaker, and a gravimetric feeder. In a progress report (*7*) on seven mills, issued in 1956, various arrangements of this basic idea were described. The advantages of the two-stage arrangement are: (1) leveling out of kiln surges (which helps to control the level of causticity by providing additional detention time for slaking); (2) utilizing the sensible heat in the hot lime, and thereby eliminating the need for green liquor heating; and (3) reducing both the equipment and maintenance previously required to handle the hot lime. A typical indoor installation is shown in Fig. 2.

Since the last report, the number of mills practicing two-state slaking has now increased to over twenty. Because of layout restrictions and personal preferences, various arrangements of the hot lime conveying equipment, lime and liquor by-passes, new and reburned lime bins, and lime feeders have resulted.

The flowsheet shown in Fig. 1 illustrates a fairly simple arrangement which has the following advantages:

1. Hot lime handling is reduced to a single inclined pan conveyor which is both reliable and low in maintenance as compared to combinations of drag and bucket elevators.
2. The reburned lime bin may be eliminated together with its hot lime feeder and conveyor.
3. The fresh lime bin may be serviced by either an air conveyor system or a cold lime elevator.
4. Bypassing the primary unit is easily accomplished through the use of a flip-gate.
5. The relatively short inclined pan conveyor allows for some

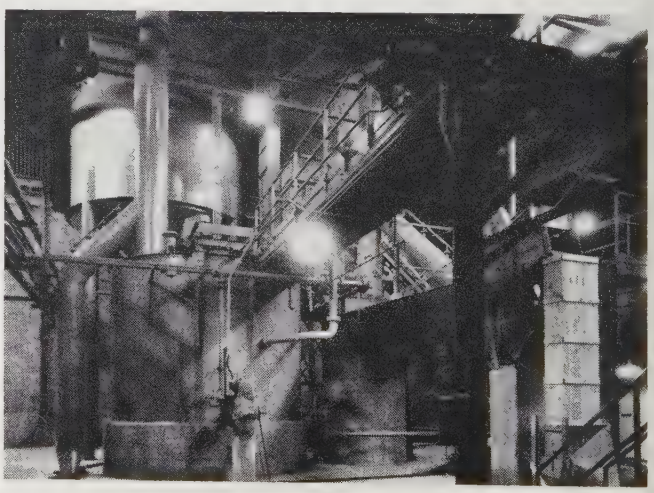

*Fig. 2. An indoor installation of primary and secondary slakers*

cooling of the lime, and helps control overheating which causes boil-overs.

6. The hot lime crusher reduces oversized lumps to a size which is easy to handle in the conveyor and the primary slaker.

The case for two-stage slaking is not that clear-cut, however, since several mills have reported that slaking of hot lime in the large volume primary unit results in a faster settling carbonate mud than anticipated. This has caused problems at some mills where particularly rapid settling sludges have caused temporary overloads in the lime mud washer and occasionally also in the white liquor clarifier.

The production of a fast settling mud has always been one of the objectives of the slaking step in order to reduce to a minimum the unit area requirements in both clarifier and mud washer. Current studies by Dorr-Oliver in southeastern mills give some evidence of the faster settling muds but additional data are needed to confirm this.

Grit removal from the primary remains a potential problem spot. From the standpoint of maximum lime utilization, the recirculation of oversize solids (partly grit but mostly unslaked lime) is desirable; however, trouble-free pumping of this hot, reacting heterogeneous mass is difficult to attain. Plugging, when it occurs, is usually in the suction line of the recirculation pump. It is obvious that the pump should be placed as close as possible to the tank, and the suction line kept free of unnecessary turns and fittings. A number of mills have provided a grit purge line direct to the classifier section of the secondary slaker so that excessive build-up of unslakable material in the lower section of the primary can be prevented during periods of off-quality reburned lime.

With the primary providing about 90-min. retention time, the secondary slaker, under normal operating conditions, handles the slaking of the new lime makeup and also the classification, de-liquoring, and washing of all the grit. This unit should be sized to handle the entire lime requirements of the mill in case of kiln or primary slaker shutdown and also startups. Likewise, the causticizers should provide a minimum of 60-min. retention to insure that maximum conversion is attained when all the lime is entering at the secondary slaker. When the primary unit is in operation, this retention time may be reduced by by-passing one of the causticizers.

## WHITE LIQUOR CLARIFICATION

If properly causticized, the slurry is now ready to yield substantially clear white cooking liquor and thick lime mud. This is most easily accomplished in one of several available designs of white liquor clarifiers. The most familiar and the most economical, from a space standpoint, is the four-compartment balanced tray design. Where space is not a controlling factor, two-compartment balanced tray and single-compartment designs offer greater operating simplicity.

In Fig. 3 is shown a new tray design clarifier (Type ATV) which has already been proved highly efficient in the thickening of carbonate muds in the sugar industry. No feedbox is required since all the feed enters through the Type FF feedwell (previously described), and is automatically divided equally between the compartments by means of vertical concentric-type feed distributors. As many as four compartments have been used. A labyrinth seal between compartments permits separate mud withdrawal from each compartment, thereby providing positive mud removal control, and eliminating any possibility of re-dilution of thickened muds (possible in balanced tray design). Clarified liquor from the lower compartments flows through internal bustle pipes to a single overflow box where it is joined by the upper compartment launder effluent.

Through the use of the new type FF feedwell and deeper compartments, detention efficiencies obtained with the new tray design are comparable to those of unit type clarifiers. This means that the modern tray type machine may be designed with confidence on the basis of 10 to 12 sq. ft. of thickening area per ton per day of lime mud at 40% solids underflow concentration. This reduction of 25 to 37% in the area requirement results in lower capital costs without sacrificing the space-saving advantages of the tray design.

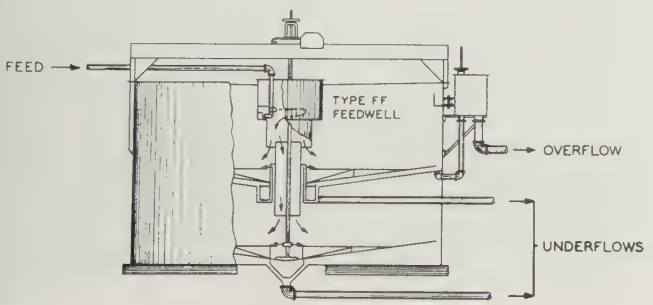


*Fig. 3. Dorr white liquor clarifier—Type ATV*

## WHITE LIQUOR POLISHING

Because of the trend toward extreme brightness in pulps in recent years, the need for a very clear white liquor has increased. A properly sized and operated white liquor clarifier produces a liquor which is quite clear to the eye. Such a liquor will usually contain less than 100 p.p.m. of suspended solids. For most mills this clarity is perfectly acceptable, particularly where bleaching is not involved. For high brightness pulps, an exceptionally clear white liquor can be produced by removing the last traces of suspended contaminating solids in a polishing filter.

A white liquor polishing station normally consists of a battery of three filters similar to those shown in Fig. 4. The design is similar to the rapid sand filters used in water treatment plants. This unit contains a bed 53 in. deep containing carefully graded and sized anthracite coal. Suitable baffles and underdrain systems insure uniform distribution of the liquor as it filters down through the bed. The very fine suspended solids are deposited in the upper portion of the bed, producing a sparkling clear cooking liquor.

Under normal operating conditions, the average filtering cycle time is about 24 hr. so that backwashing is ordinarily necessary only once per day. During the backwashing operation, a motor-driven rake agitator breaks up any agglomerations, and frees the media from suspended solids, leaving a perfectly conditioned bed for the next filtering cycle.

The polishing station also serves as a safeguard against cloudy white liquor caused by slow settling lime mud. These occasional upsets may result in a considerable amount of carbonated mud being sent to the white liquor storage tanks and sometimes on to the digesters. It also prevents those infrequent but costly appearances of off-color pulp by efficiently filtering out the metallic slimes which contribute to this condition. Six polishing installations of this type are currently in use.

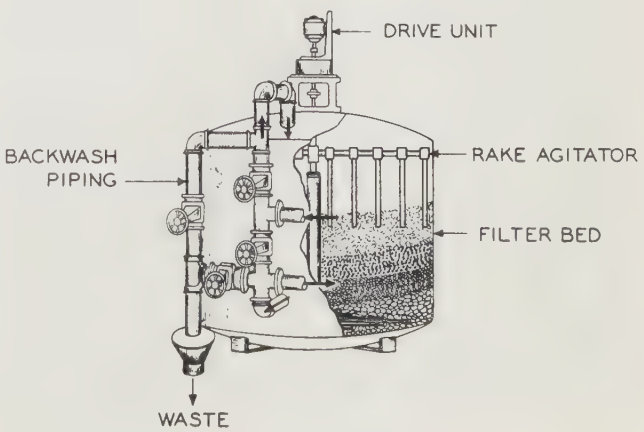


*Fig. 4. Dorrco white liquor polisher*

## LIME MUD WASHING

The trend in this operation continues to be in the direction of two-stages of mud washing in a four-compartment tray thickener. A properly operated white liquor clarifier will produce an underflow containing between 35 and 40% solids. Wash water in the modern plant is made up of four different streams: (1) fresh wash water, usually evaporator condensate; (2) dust collector scrubbing water; (3) effluent from the filter or centrifuge dewatering the lime mud; and (4) dregs washer overflow.

Lime mud washers are designed on the basis of providing 7 to 8 sq. ft. per ton of lime mud per day. The higher figure gives greater assurance of clear overflows and, therefore, no lime loss through the weak wash system. Good operating practice calls for lime mud washer underflows in the range of 38 to 40% solids. This allows some leeway for adjustment of the solids concentration ahead of lime mud dewatering. Proper washing results in a lime mud containing less than 1% $Na_2O$ based on the dry solids.

## LIME MUD DEWATERING

In most mills, the lime mud is dewatered on a rotary drum-type vacuum filter which produces a cake containing 40 to 45% moisture. If an adequate two-stage mud washing system is available, little or no additional washing of mud is required. During periods when additional washing might be required, displacement washing is easily accomplished by means of showers on the filter.

Kilns with properly designed recuperating systems can handle a lower moisture content feed, thus effecting fuel economics. Kiln feeds containing 25 to 35% moisture have been produced on a filter by a new "precoat" technique developed in a Canadian mill. This consists of forming a precoat on the drum of about $^1/_2$ in. of lime mud, and continuously removing the top $^1/_8$ in. of new solids using a fixed scraper as shown in Fig. 5. The precoat is renewed once per shift. By producing a filtrate containing well below one per cent solids, the technique insures that there will be no build-up of circulating fines in the mud washer system. Build-up of fines results in loss of mud washing capacity and loss of lime through muddy overflows. This condition sometimes occurs when centrifugation is used as a means of dewatering lime mud since the centrifuge actually classifies the mud particles and returns the extremely fine particles to the mud washer. The centrifuge, however, has advantages in its compactness and completely enclosed installation.

## LIME CALCINATION (*8*)

The trend in kiln design continues to be in the direction of higher length to diameter ratios. Whereas in 1948 two-support kilns with ratios of 18 to 1 were common, present designs call for four or more supports and ratios are 30–35 to 1.

The trend toward using one large unit rather than two or more smaller units has resulted in better fuel economy at lower capital cost, but at the expense of some flexibility. Improvement in fuel economy is evident in comparing fuel requirements in 1947 of 10 to 12 million B.t.u. per ton of lime versus today's figures of 7 to 8. Improvements in heat reclaiming, such as improved chain sections and novel heat recuperators, account for most of the improvement in fuel economy.

The past 12 years have also seen considerable emphasis placed on dust collection. The use of efficient wet type scrubbers on the kiln stack gases has not only improved lime recovery but also has improved working conditions in the kiln area.

## HOT LIME CRUSHER

One of the kiln operator's headaches has been solved in a number of mills, particularly in the northwest, through the use of a hot lime crusher immediately following the kiln. In most cases, the grizzly is removed, and the kiln discharge dropped directly into the crusher.

The rugged unit consists simply of a rotating shaft equipped with specially designed teeth which mesh with fixed blades on the side of the hopper. The openings are spaced so that everything below about 2 to 3 in. will pass through, but larger lumps will be held and reduced to that size. The hopper walls and shaft are water-cooled. Originally developed on the west coast, this type of crusher is now installed on 13 kilns.

## PUMPING

As in the other processes involving thickening of slurries, close control of underflow quantities and densities in the recausticizing system is vital for maximum chemical recovery. The diaphragm-type metering pump with its positive displacement suction stroke, easy stroke adjustment and visible mud discharge is still the favorite in most sections of the country. Improvements in design, and initial installation of larger capacity pumps provide the flexibility needed to handle the wide range of mud flows necessary in meeting the liquor demands of the modern pulp mill.

An example of a rugged, dependable metering pump for handling heavy mud slurries is the Type W diaphragm pump shown in Fig. 6. Maintenance characteristics are much improved over the Type VM and diaphragm life in excess of twelve months has been reported.

In some mills centrifugal pumps with variable speed drive are used on thickener underflows. The problem of controlling pump output with fluctuating mud densities remains unsolved

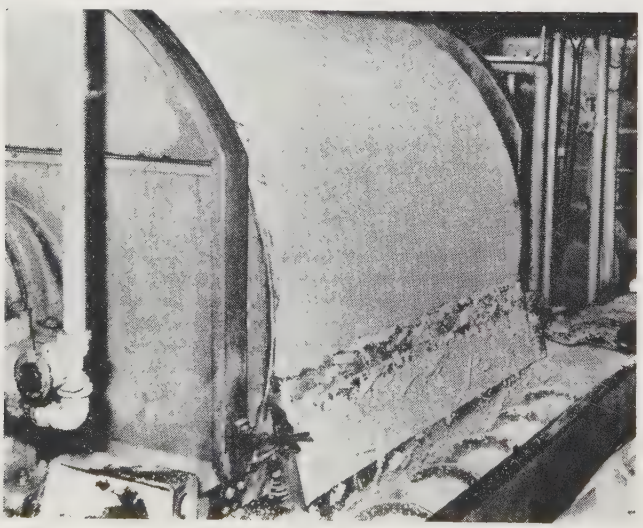

*Fig. 5. A 6 x 6 ft Oliver lime mud filter using the "precoat" technique in a Canadian mill*

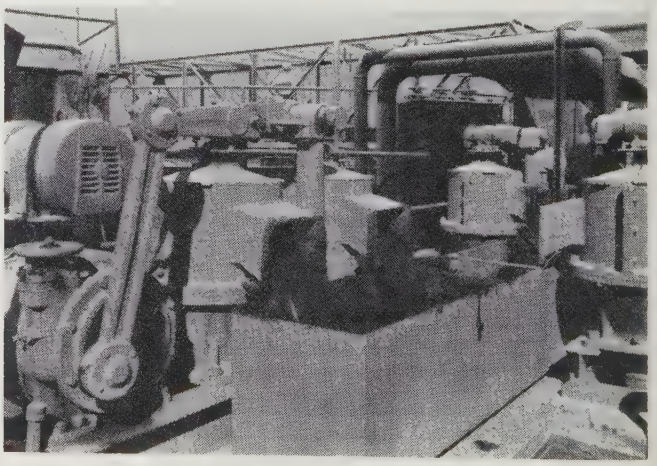

*Fig. 6. A Dorrco Type W diaphragm pump handling heavy lime mud slurry in a southeastern mill*

unless somewhat complicated and expensive density controls are added.

Several mills in the northwest have recently pioneered the use of the air-actuated type ODS* diaphragm pump on both lime mud slurries and green liquor dregs. Early operating results showed the need for changes in ball valve design and diaphragm construction to increase length of service under hot caustic conditions. Improvements now being tested give indications that this pump may provide a lower cost answer to the metering and transferring of these slurries against high discharge heads in smaller mills.

### GENERAL TRENDS

From the above it can be stated that the general trend in continuous causticizing practice is toward simplification in equipment design and operation. Future plants will include automation aimed at improving process control with less operating labor and supervision. Plant design improvements will feature compactness and a better opportunity for good housekeeping. Through continued attention to sources of chemical losses, alert operators have been able to achieve recovery efficiencies of over 99% on soda and 97% on lime. To accomplish this consistently while producing a higher quality cooking liquor at lower overall cost—this is the challenge of the future.

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* ODS is a trademark of Dorr-Oliver, Inc.


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# Chemical Pulp from Groundnut Shells


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ARTIFICIAL silk production started a revolution in Science and Industry. Its importance is still on the increase despite the invention of other synthetic, inorganic, protein, and other fibers. Cellulose fibers constituted 28% of the total man-made fibers in 1957. With increasing demand for them, search for raw material sources is also widening. In the past few decades many sources have been explored and added to the list of old ones: cotton linters. Starting from hard and soft woods, to different types of grasses, cereal straw, bamboos, potato shells, and bagasse. Recent additions being groundnut shells (*1*), rice straw (*2*), and sunflower reeds (recently reported from the Chinese People's Republic).

*Fig. 1. X-ray diffraction pattern of groundnut shells*

### AIM OF INVESTIGATION

An attempt has been made to find a possibility for using groundnut shells for producing chemical pulp. The world produce of groundnuts in 1954–1955 was nearly 10 million tons, providing 2.5 million tons of shells (calculated at 25%) from which some 875,000 tons of pulp (taken as 35%) can be produced yearly without extra cultivation.

### EXPERIMENTAL

To decide on a pulping method, first an x-ray diagram and chemical analysis were made. The results are shown in Fig. 1 and Table I.

From Fig. 1 it is clear that the fibers are short and as such, for a higher yield, the use of the alkali process and high temperature are to be discarded. In Table I the effect of roasting and washing is quite clear; washing can be very profitable for pulping (prehydrolysis).

#### *Washing*

For washing, the shells were kept in distilled water for 24 hr. at room temperature (20°C.), and then were heated to 60 to 70°C. for 1 hr., washed and filtered.

As is evident from Table I, there is much resinous matter, and hence sulfite process is also not advisable since resins are partly soluble in sulfite cooking. To achieve higher yield, and a pulp free from resins and having higher viscosity, and the best method appears to be the sulfate. Various cellulose

**Table I**

| | *Ash, %* | *$SiO_2$ in ash, %* | *Ether extract, %* | *Water extract, %* | *Moisture, %* | *Jansen Norman cellulose, %* | *Cross and Bevan cellulose, %* |
|---|---|---|---|---|---|---|---|
| Unroasted Unwashed | 3.477 | 16.071 | 9.073 | 12.1 | 8.331 | 35.2 | 36.64 |
| Unroasted Washed | 1.698 | 14.7 | 1.195 | .. | ... | .. | .. |
| Unwashed Roasted | 2.057 | 16.2 | ... | 16.6 | ... | .. | ... |

sources given in Table II, and some important compositions are shown.

**Table II**

| | *Cellulose, %* | *Moisture, %* | *Ether extract, %* | *Ash, %* | *$SiO_2$ in ash, %* |
|---|---|---|---|---|---|
| Groundnut shells (*1*) | 36.64 | 8.331 | 9.073 | 3.477 | 16.071 |
| Cereal straw (*3*) | 36.0 | .. | 1.3 | 8.7 | .. |
| Linters (*4*) | 80–85 | 6.0 | 1.0 | 1–1.5 | .. |
| Rice straw (*2*) | 42.8–45.8 | .. | 6.4[a] | 19.55 | 15.71 |
| Bagasse, Brazilian (*5*) | 52.0 | 11.80 | 3.8[a] | 3.8 | .. |
| Wheat straw (*6*) | 50.2 | .. | 4.1[a] | 6.5 | 69.0 |
| Birch wood (*7*) | 60.4 | .. | 3.2[a] | 0.5 | .. |
| Spruce wood (*7*) | 60.6 | .. | 2.3[a] | 0.3 | .. |

[a] Alcohol-benzene extract

### *The Sulfate Method*

Here the sulfate method was used by varying sulfidity, temperature, and alkalinity. For all the experiments an electrically heated, 10-liter autoclave was used, where the temperature could be controlled by ±5°C. In all the experiments the liquor ratio was 1:5. The sulfidities tried were 30, 33, 36, and 40%; but it was found that 33% sulfidity was the best for pulping. The alkalinities investigated were 27, 30, 32, 35, 37, 39, and 40%. The temperature was varied from 140 to 170°C., and the time from 3 to 7½ hr. As a result of these experiments, it was observed that the temperature and alkalinity can neither be raised too high nor decreased too low (Table III).

**Table III**

| *Temperature, °C.* | *Alkalinity calcd. as $Na_2O$, %* | *Time, hr.* | *Pulp, %* |
|---|---|---|---|
| 140 | 40.0 | 7.0 | 32.70 |
| 150 | 40.0 | 5.5 | 35.4 |
| 160 | 32.0 | 4.0 | 35.71 |
| 170 | 30.0 | 3.0 | 30.8 |

An x-ray diffraction pattern of the 150°C. pulp was taken (Fig. 2), and its chemical analysis, with some of the other important pulps, is given in Table IV.

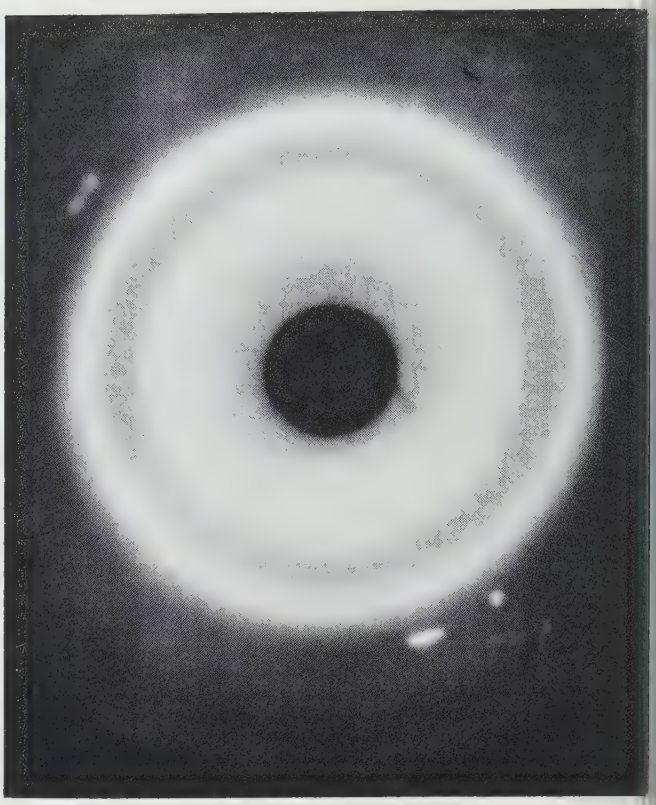

***Fig. 2. X-ray diffraction pattern of groundnut shells cellulose***

**Table IV**

| *Cellulose source* | *Cellulose, %* | *α-Cellulose, %* | *Ash, %* | *Iron, mg.* | *D.P.* | *$SiO_2$ in ash, %* | *Lignin, %* | *Extract of benzene-alcohol, %* |
|---|---|---|---|---|---|---|---|---|
| Groundnut shells | 35.4 | 92.0 | 0.8 | 35 | 340 | 40.56 | 0.32 | 0.71 |
| Cereal straw (*3*) | 36.0 | 88.0 | 0.3–0.4 | 7 | 700–800 | .. | ... | .. |
| Purified linters (*4*) | .. | 99.0 | 0.1 | 2 | 1440 | .. | 0.2 | 0.2[b] |
| Rice straw (*2*) | 42.8–45.8 | 71.5–83.7 | 13.3–0.73 | .. | 628–840 | .. | 1.1–4.2 | .. |
| Brazilian bagasse (*5*) | 52.0 | 69.7 | 0.58 | .. | ... | 71.0 | ... | .. |
| Egyption bagasse (*8*) | 28.1 | 93.0 | 0.10 | .. | 822 | .. | 2.6[a] | 0.6[a] |
| Wheat straw (*6*) | 50.7 | 78.7 | 0.99 | .. | ... | 69.0 | ... | .. |
| Birch (*7*) | 60.4 | 68.4 | 0.15 | .. | ... | .. | ... | .. |
| Spruce (*7*) | 60.6 | 72.2 | 0.12 | .. | ... | .. | ... | |

[a] Unbleached.
[b] Ether extract.

## CONCLUSION

From these experiments it is evident that a chemical pulp suitable for the rayon industry can be produced. By using water prehydrolysis before sulfate cooking, a pulp fit for viscose and cuprammonium rayon can be obtained. This pulp was found suitable for producing cellulose films, and it is hoped that it can be a good raw material for the lacquer industry. It can be economically produced as the shells ar waste product of the oil industry and the chemicals used ar comparable with other cellulose sources; they require no extr plantation and if the shells are powdered, with the consequen reduction in the cost transportation.

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Received Aug. 1, 1959.

The author is grateful to his elder brother, J. Sahai Govil, I.P.O., Dehradun, India, for supplying the groundnut shells for these experiments.

# Refining and Refining Systems for NSSC Hardwood Pulps

G. E. SOYKA

THE increasing demand for more fibers for the manufacture of paper has necessitated the use of hardwoods as a supplementary fiber supply. Hardwood pulps are now being used in practically all furnishes and this fact makes it interesting to examine the refining and refining systems best suited for this type of pulp, and which will allow their use to the best economical advantage. Lately several papers were published. Among these we specifically take reference to Robert W. Hisey's article, the author's article on refining of short-fibered pulps, and of general interest is the work done by George Jayme and Klaus Rosefeld.

The findings of the latter were rather interesting because they developed fibers by treating them with ultrasonics and subsequent beating in a rubber-lined Jokro mill. They were able to develop simultaneously very high test values without any appreciable fiber-length reduction. In order to approach these phenomena commercially the work here was undertaken. Neutral sulfite semichemical (NSSC), pulp falls into this class of short-fibered pulp and this is an attempt to contribute to the art by having done refining studies on two selected unbleached neutral semichemical pulps, one made of poplar and the other of mixed hardwoods, both grown in the central United States. It is not attempted here to evaluate test methods nor theorize on the basic concepts of refining; rather some studies are presented to show an attempt for a practical evaluation of pulp strength development and capability which became apparent during the various stages of refining levels.

## REFINING STUDIES

In selecting a pulp for use in the manufacture of a specific paper or board, usually the standard Valley beater test curve is considered on accepted indication of strength capability and from these data comparisons are made as well as furnishes planned. However, the limitations presented by this beater test are manifold, and in some cases the tests are misleading, as is in the case of short-fibered chemical hardwood pulps and especially on NSSC pulps. It has been found that in the latter case the beater test is quite inaccurate in regard to tear resistance as it has been established that these pulps yield ultimately better tear strength when properly refined than can ever be anticipated from the beater evaluation.

A factor worth mentioning is that although rather extensive tests were run, it is very difficult to state that the same pulp differently refined but having practically identical strength curves, freeness, fiber length distribution, and even looking similar under the microscope, will have absolutely the same properties. The behavior on the machine might differ as to forming properties, internal bonding, and other characteristics for which we have either no test or attempts at test methods might vary from mill to mill. But for all practical purposes the results obtained were found to be reproducible in mill practice as to the burst, tear resistance, tensile and folding endurance test. As with other pulps, the picture will be different whether slush, lap, or dried pulp is considered, even if it is from the identical cook.

***Neutral sulfite semichemical pulp unbleached (poplar)***

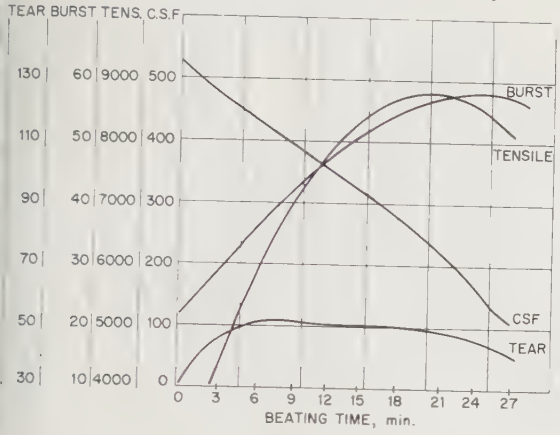


*Fig. 1. Valley beater*

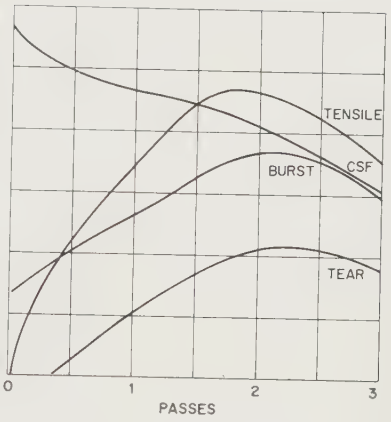


*Fig. 2. Steep angle refiner—alloy iron cast tackle*

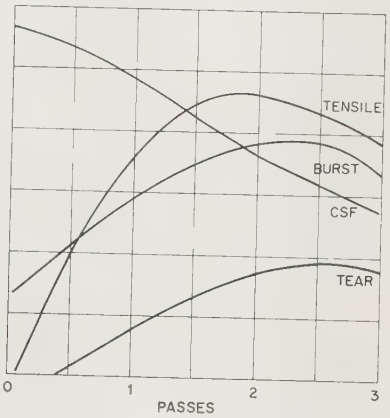


*Fig. 3. Single disk refiner*

| | Fig. 1. | | | | Fiber Classification Fig. 2 | | | | Fig. 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. 14 | 0.3 | 0.0 | 0.1 | 0.0 | 0.2 | 0.3 | 0.0 | 0.1 | 0.2 | 0.5 | 0.2 | 0.0 |
| No. 30 | 17.6 | 16.1 | 11.2 | 7.2 | 18.0 | 16.4 | 17.0 | 15.0 | 18.0 | 18.4 | 19.2 | 16.3 |
| No. 50 | 47.1 | 42.2 | 40.0 | 25.3 | 46.3 | 47.2 | 45.3 | 46.0 | 46.3 | 40.2 | 36.3 | 29.3 |
| No. 100 | 22.0 | 21.0 | 16.0 | 17.2 | 21.0 | 16.0 | 17.1 | 15.7 | 21.0 | 19.3 | 22.4 | 22.0 |
| Fines | 13.0 | 20.7 | 32.7 | 50.3 | 14.5 | 20.1 | 20.6 | 23.2 | 14.5 | 21.6 | 21.9 | 32.4 |

The tests shown below were conducted with several purposes in mind. To develop strength without significant fiber-length reduction was important and to be able to refine in such ways as to favor one or more strength characteristics, depending on the requirements of the paper to be manufactured. Another purpose was to find the ultimate strength that could be developed in selected commercial refiners in order to have a practical approach to the problem. To have a comparison the Valley beater test was run on both pulps.

It also was found necessary to check some of the development microscopically. In wet state, before the fibers dried, the phase contrast microscope was used and it was possible to draw some interesting conclusions which are reported in connection with the individual studies.

The series of development studies below is on the NSSC poplar pulp, wet lap 35%. Figure 1 shows the Valley beater curve, Fig. 2 the development in a steep angle conical refiner, and Fig. 3 the development in a single disk refiner.

It is noteworthy that the beater development shows a lower tear and tensile development at their peak at lower freeness than both refiner developments. Burst strength is slightly higher than with the refiners. But most important is to note that in both refiners burst, tear, and tensile are simul-

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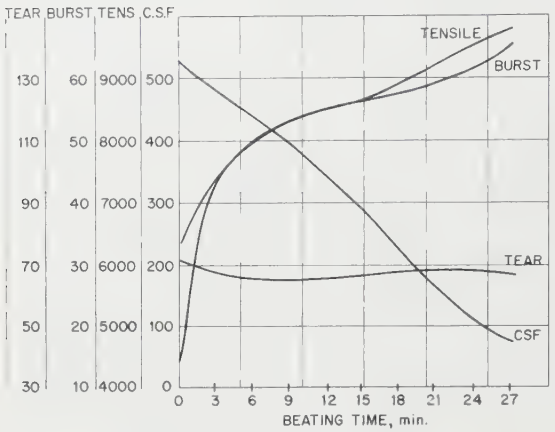


*Fig. 4. Valley beater test*

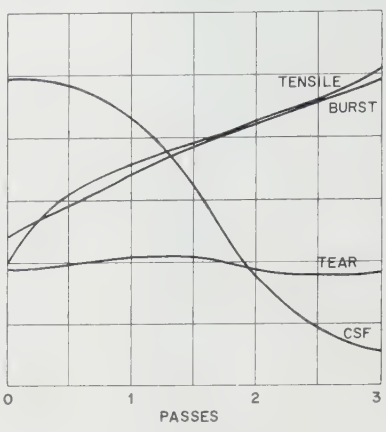


*Fig. 5. Steep angle refiner—alloy iron cast tackle: plug operated in reverse*

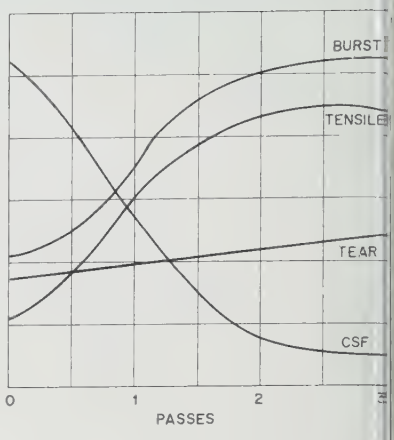


*Fig. 5A. Steep angle conical refiner—alloy iron cast tackle*

*Fiber Classification*

| | Fig. 4 | | | | Fig. 5 | | | | Fig. 5A | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. 14 | 0.2 | 0.3 | 0.4 | 0.0 | 0.7 | 0.3 | 0.2 | 0.1 | 1.2 | 0.1 | 0.1 | 0.1 |
| No. 30 | 10.4 | 4.9 | 3.6 | 3.0 | 28.6 | 24.3 | 14.2 | 11.2 | 19.6 | 19.7 | 14.9 | 13.6 |
| No. 50 | 56.6 | 51.0 | 46.8 | 42.0 | 43.4 | 45.2 | 45.8 | 42.0 | 50.3 | 43.4 | 41.8 | 41.3 |
| No. 100 | 27.0 | 32.0 | 34.0 | 31.7 | 18.4 | 20.4 | 23.2 | 24.7 | 20.9 | 21.1 | 23.6 | 23.8 |
| Fines | 6.8 | 11.8 | 15.2 | 23.3 | 8.9 | 9.8 | 16.6 | 22.0 | 8.0 | 15.7 | 19.6 | 21.3 |

taneously at their highest level, which incidentally occurs at a higher freeness level than with the beater.

Considering the fiber classifications the picture is even more impressive as both refiners did not seem to affect significantly the fiber length distribution whereas the beater decidedly shortened the fibers at the highest level of tensile.

The results from the two refiners are almost identical, except that the disk refiner showed a lower tear maintenance at a higher burst development. At these tests we attempted to evaluate the power required to refine the stock to the same level, but because of difference in capacity and size of the refiners the results were not comparable. Subsequent trial runs on other short-fibered pulps showed approximately equal power requirements. A further study was run on the NSSC pulp made from mixed hardwoods. The tests here comprise the Valley beater evaluation and runs on the steep angle conical refiner. These tests were performed to show the different methods in which this pulp can be developed with the minimum of fiber length reduction. In order to illustrate this, Figs. 4 to 6 were recorded when changes were made in the metal of the tackle and by different methods of operation of the refiner.

In all these studies the refiners were operated at the same consistency and the same design tackle. Study 5 was run at low throughput and study 5A at high throughput, in both these cases the tackle was of cast alloy iron. Study 5 shows a similar development as the Valley beater but on a lower level; study 5A shows a much better tear and burst and the fold (see Fig. 8) is practically equal to the beater curve. Study 6 was run with the same tackle but made of stainless steel and of particular interest is the extreme development of the tear resistance.

At the time these studies were concluded fold was of particular interest to the author and several methods were tried to get the highest possible folding endurance test. The following might well illustrate that the present test methods and refining methods do not always give the desired pulp capabilities for specific strength development. After several futile attempts with different methods of refining it was found that Norton abrasive stone disk No. 32436–18vbe, 3 in. in diameter, attached to the spindle of the TAPPI disintegrator agitated at 5000 r.p.m. gave the charted strength development in Figs. 7 and 8. The procedure was to agitate the NSSC pulp from mixed hardwoods (the same as in the above study series) for 6 hr. at a consistency of 1.25%.

Although the foregoing method is not commercially economical it does show that a pulp of this kind is capable to give at a Canadian Standard freeness of 1 ml., an MIT folding endurance test of 1056, and it should be noted that the tear resistance stayed above the original level. Further, the resulting handsheet did not appear like glassine but rather like a bond sheet, having a shrinkage of only 8%. All these facts indicate that there is a wide field for investigation and study and eventual practical application of such findings.

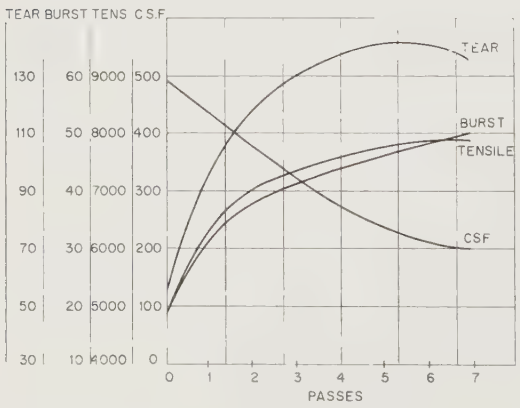


*Fig. 6. Steep angle conical refiner—stainless steel tackle*

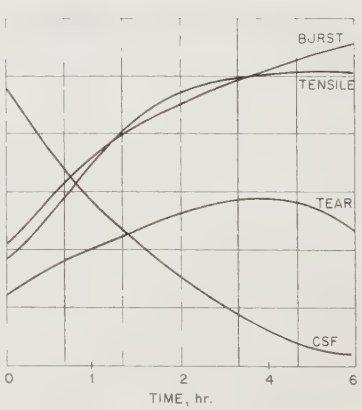


*Fig. 7. TAPPI disintegrator—Norton abrasive disk No. 32A36-18VBE 3 in. diam.*

*Fiber classification*

| | Fig. 6 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| No. 14 | 7.1 | 1.4 | 0.3 | 1.7 | 0.0 | 0.3 | 0.1 | 0.0 |
| No. 30 | 26.8 | 13.6 | 14.9 | 13.3 | 9.0 | 8.7 | 7.9 | 6.8 |
| No. 50 | 36.9 | 48.1 | 47.4 | 47.3 | 49.6 | 47.3 | 48.0 | 46.8 |
| No. 100 | 21.1 | 29.8 | 27.0 | 29.2 | 29.4 | 31.1 | 30.0 | 32.3 |
| Fines | 8.1 | 7.1 | 10.4 | 9.5 | 12.0 | 12.6 | 14.0 | 14.1 |

*Fiber classification, % retained*

| | Fig. 7. | | | | |
|---|---|---|---|---|---|
| No. 14 | 6.3 | 0.4 | 0.5 | 0.5 | 0.3 |
| No. 30 | 18.4 | 6.4 | 9.9 | 6.3 | 12.5 |
| No. 50 | 48.2 | 53.5 | 52.8 | 49.4 | 45.6 |
| No. 100 | 20.2 | 31.9 | 26.8 | 29.4 | 25.5 |
| Fines | 6.9 | 7.8 | 10.0 | 14.4 | 16.1 |

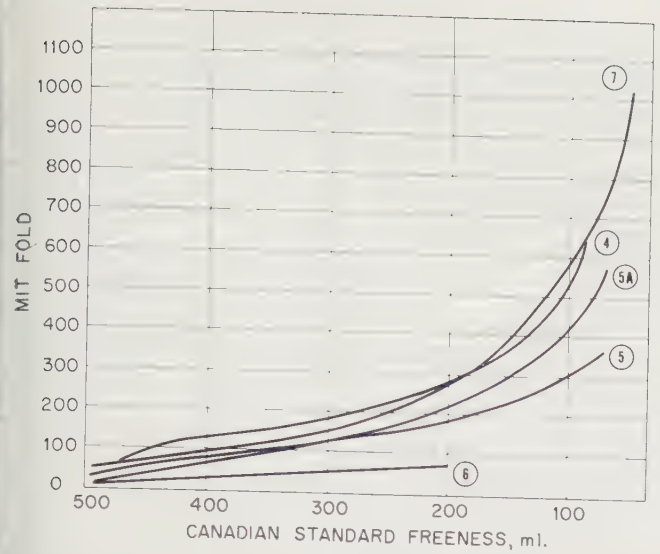


*Fig. 8. Folding endurance—NSSC unbleached (mixed hardwoods)*

## REFINING SYSTEMS

In order to utilize such refining and maintenance of fiberlength in all NSSC pulp or mixed furnishes, it is of economic advantage to arrange the refining system in such a way as to take fullest advantage of the strength primarily developed and also to have enough refining or jordaning in order to have the necessary control for proper machine operation and formation problems. We have put these ideas into practice at several mills and found them very successful. The arrangement of the refining system necessarily will have to be suited to the furnishes planned. It should probably be quite flexible, and particularly in specialty mills some compromises will have to be made.

Considering many present-day systems it is found that the total furnish is jordaned before going on the machine. That means in order to get better formation the whole furnish is more or less severely shortened in fiberlength in the attempt to produce the proper drainage conditions, or produce the fines necessary to give good formation.

As it is with NSSC pulp, the fibers are already comparatively short to start with. Further, as outlined, the pulp will be carefully refined to its peak development and any further refining or jordaning will take it over the peak and the loss in certain strength characteristics is irrevocable.

Inasmuch as there has to be a tool for the operator to have control over the drainage and forming characteristic of the furnish, fractional refining is indicated in the proper refining system. By fractional jordaning or refining it is understood that only a certain predetermined portion of the total furnish is jordaned thereby giving the operator the needed control, and on the other hand maintaining in the remainder of the furnish fiberlength and developed strength levels.

The fraction necessary to be passed through the jordan will depend on the grade made and the furnish, as well as the prerefining. This fractional jordaning is shown on all three flow diagrams. One of the necessary features in such a setup is a flow metering and automatically proportioning system. This is necessary whether a continuous or batch refining system is used. This system necessitates a magnetic flowmeter, motorized stock valves, and a control panel with an automatic proportioning system.

The magnetic flowmeter is only installed on one line; the valves can be preset so that each will deliver a certain ratio of the furnish. The total volume control is on the line with the flowmeter. If this total volume is changed, then the valves will adjust automatically, still maintaining the same ratio of flow. In order to simplify the layout, no crossover piping was indicated, nor was the possibility of parallel and in series refining given. The systems shown should only illustrate the basic concept of the possible refining methods and of fractional jordaning. The schematic refining systems here shown are an attempt to illustrate basic design assuming a mixed furnish. Basically three principles can be used: (1) to refine each furnish constituent separately, (2) to prerefine the hardwood pulp before mixing with the other furnish constituents, and (3) if these two methods are impractical, to do only fractional jordaning.

## CONCLUSION

The limited studies performed on NSSC hardwood pulp show that it is possible to refine this pulp to higher strength levels at higher freeness than the standard Valley beater test indicates, as well as maintaining optimum fiberlength. It is also indicated that further work might develop commercial methods of refining in which certain test levels could at arrived at, practically in the ranges of long-fibered pulps.

***Refining system for NSSC hardwood and long-fiber pulp—refined together***

——— Stock lines  - - - - Electric connection for flow control systems

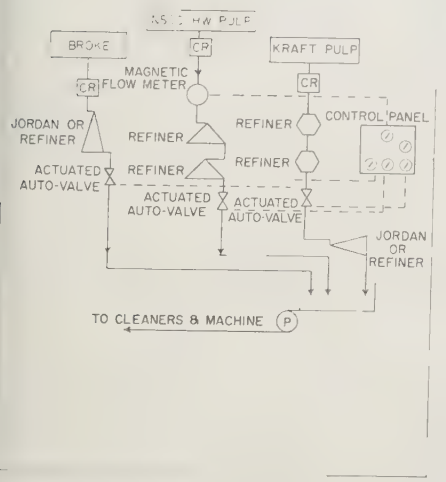


*Fig. 9. Separate refining*

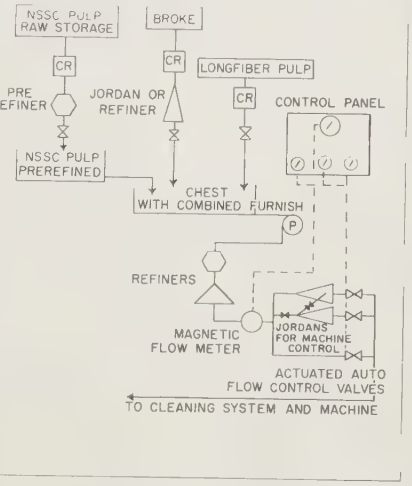


*Fig. 10. Prerefining of NSSC pulp,—combined refining of furnish, fractional machine control refining (jordaning)*

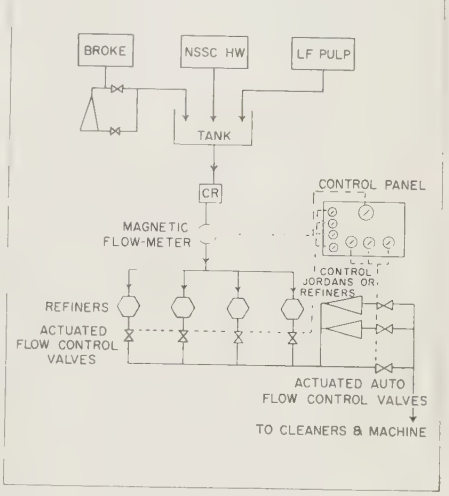


*Fig. 11. Fractional control refining*

The fact that NSSC hardwood pulp can be developed in a way to have at the same freeness level optimum burst, tear, and tensile makes it attractive to design a stock preparation system which will allow this furnish to go on the machine with the minimum strength deterioration through necessary control refining. A refining system of this type might give economic advantages, by possible reduction in long fiber furnish addition or might promote the use of less expensive pulps, as well as promote the use of short-fibered pulps in grades not yet utilizing them.

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# Instrumenting the Experimental W-P Recovery Process


JAMES W. TAYLOR


In the spring of 1957, Consolidated Water Power & Paper Co. of Wisconsin Rapids, Wis., approved plans for building an experimental plant for the recovery of semichemical and soda base sulfite cooking liquors. The project, employing the Western Precipitation Corp. process, cost three quarters of a million dollars and has been in operation since early 1959.

Automation of this process was considered an important phase of the project and was indeed considered necessary toward making it a commercial success. With this in mind the instrumentation and control system was developed under the direction of Robert Q. Boyer* who set up the requirements for the instrumentation system:

1. A pneumatic type transmission system for recording and controlling process variables was required.
2. Standard component type controllers which were independent of the recorder cases and which could be regrouped or cascaded as desired.
3. Manual-automatic indicating control stations were required for all control valves, dampers, and positioners so that the entire process could be manipulated as required either on manual or automatic.
4. The same instrument and control components should be readily adaptable to a full-scale plant with the exception of certain primary measuring elements and control valves which were sized for the smaller pilot plant.
5. All transmitters were to be local indicating type.
6. All control valves must be equipped with cam type characterizing positioners and hand wheels for manual operation at the control point.

With these requirements, a system engineering job was begun

### THE PROCESS

This recovery system is designed to process both acid sulfite, and semichemical spent liquors either separately or in any proportion. At the start of the flow sheet (Fig. 1) the two liquors are combined in a mixing pump and sodium sulfide liquor is added in the first step to convert the liquor into a kraft type product. The combined mixed liquors with a high sulfidity are settled in a thickener stage to remove precipitated calcium sulfate. It is then reacted in the air oxidizer where ligonosulfonates are tied up as thiosulfates to prevent corrosion and volatilization in the later evaporator stages (*1*).

Following is a conventional multieffect kraft type evaporator and a concentrator. The final product liquor at 65% solids is sprayed in the kraft smelter. The smelt formed in the bottom of the recovery furnace is tapped into a dissolver to form green liquor and thence to the crystallizer evaporator. In this phase, sodium carbonate crystals are separated from sodium sulfide mother liquor (*2*). The crystals are washed, filtered, and re-dissolved for re-use in scrubbing the gases leaving the air heaters. The sodium sulfide liquor is diluted with raw spent liquors and then blended with the input stream as pointed out earlier.

The recovery of sodium is the start of the liquor-making system. Sulfur dioxide is absorbed in two separate towers—one an effluent gas scrubber, and the second, smaller one, an enriching tower into which makeup sulfur dioxide gas is fed (*3*). The control of pH of the effluent liquor assures the proper ratio of sulfite-bisulfite and is then available to prepare either semichemical liquor or acid sulfite liquor (*4*). By ratioing the tower effluent with sodium carbonate solution, the white liquor is returned to the semichemical department to begin the cycle.

The control system is broken down into several less complex sections and so I would choose to describe these in the following groups (Fig. 1): master mixing control, air oxidizer control, evaporator control, smelter or recovery boiler control, smelt dissolver and crystallizer-evaporator control, and $SO_2$ scrubber and white liquor-making control.

### MASTER MIXING SECTION

Beginning at the start of the process (Fig. 2) the spent sulfite and semichemical cooking liquors are brought separately or in a blend of any proportion to a mixing loop where sodium sulfide mother liquor derived from the crystallization of sodium carbonate from green liquor is blended into the mixture to achieve a controlled pH value of 11.8. This is a straight-forward pH control loop with a few interesting exceptions; we are controlling a highly alkaline and hot (about 210°F.) solution of spent liquor and sodium sulfide. The glass electrodes and temperature compensating elements were subject to rapid failure during the early days of operation. All connecting leads were carefully wrapped and waterproofed to keep out the vapor released from the sample pot. But finally the sample had to be cooled which eliminated the vapor problem. With some routine maintenance, this system now performs quite well and is a rather routine application with these few exceptions.

### AIR OXIDIZER

From the mixing loop, the liquor is settled and clarified in the thickener stage where precipitated calcium carbonate is removed from the system. From here it goes to the air oxidizer where the sulfite and sulfur is converted to sulfate sulfur in the presence of the excess sulfide ion and oxygen (Fig. 3). Flow of liquor to the oxidizer is controlled by liquid level in the foam breaker section of the oxidizer tower. Air flow is proportioned to liquor flow through an adjustable ratio relay. The ratio of air to liquor is also monitored by a Consolidated Electrodynamics Corp. Titralog $H_2S$ analyzer sampling the evaporator vents. The presence of $H_2S$ gas in the vent indicates insufficient air oxidation. This was originally intended to be a continuous monitor and automatic recorrection but until this time it has been sufficient to operate by ratio control only with periodic checking of the effluent gases.

A later modification of the oxidizer control system has been to tie the evaporator steam flow signal to the liquor to oxidizer flow control and recorrect this signal from the oxidizer level. This gives an added advantage of anticipatory control to offset the time lag between the sodium sulfide mix loop and the oxidizer through the thickener stage. We have also hooked up a remote-adjustable proportional band relay to vary the effect of the anticipating steam flow signal.


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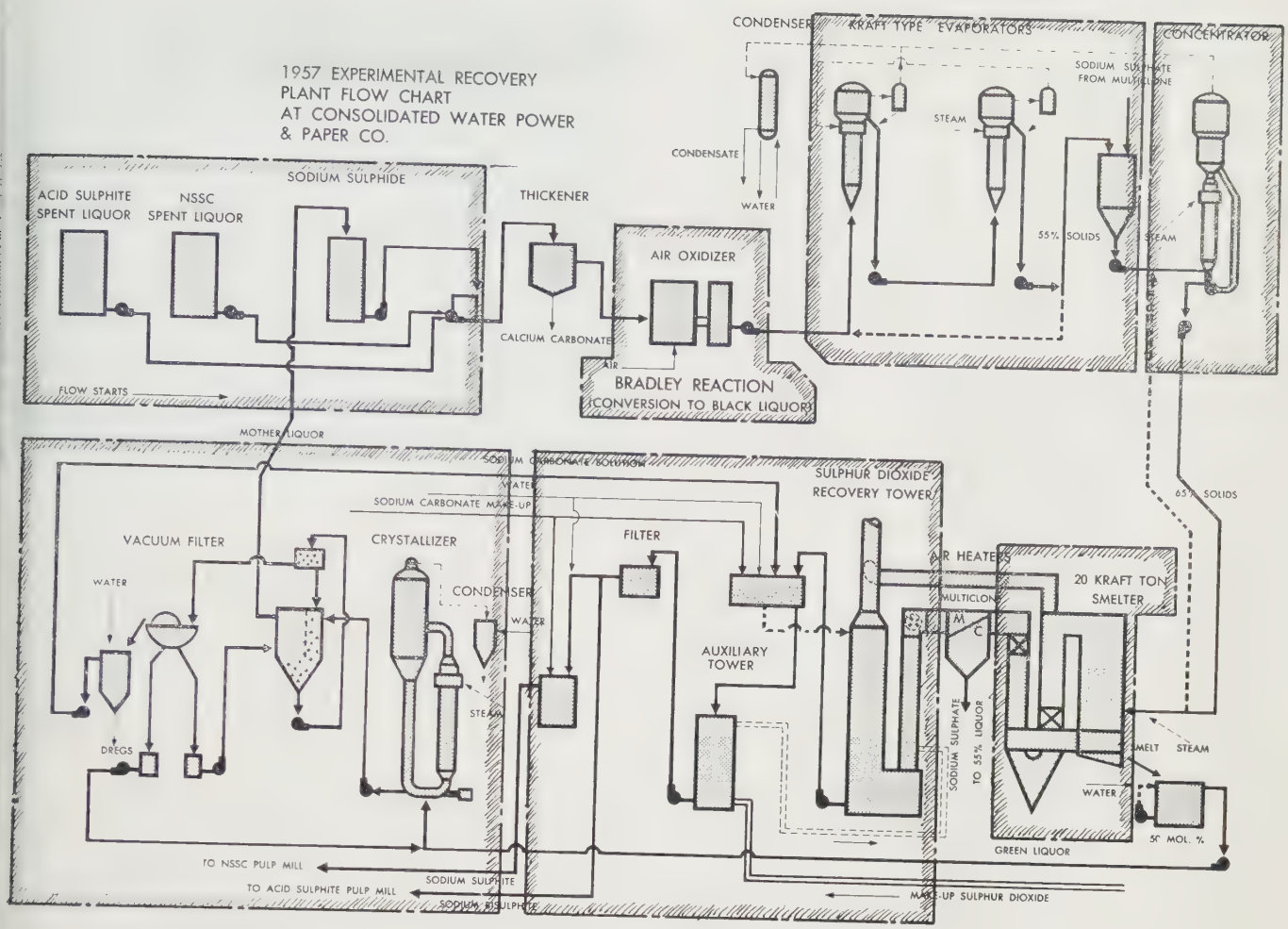


*Fig. 1. Flow sheet—WP recovery process*

## EVAPORATORS

Perhaps the most complex section of the whole system is the evaporator control (Fig. 4). This system was devised to make a two-effect evaporator work like the last two effects of a sextuple effect evaporator by recirculating heavy liquor back to the feed to raise the solids to about 25%, thereby simulating the feed to the last two effects. In early planning, it was expected that the evaporator production would follow along exactly as the recovery boiler burning rate and that feed liquor flow would follow the fuel liquor flow. This concept was abandoned after the first time the spray nozzles on the boiler became plugged and had to be blown clear with steam. It was then decided that the intermediate liquor holding tank level would be an ideal index for pacing the evaporator feed rate and the former hook-up has been abandoned.

Now the intermediate or 55% liquor storage tank level sets the rate of flow of thin liquor to the evaporators. This flow is metered and the flow signal sets the rate of steam flow in a ratioed proportion. The steam flow signal is tied back through an adjustable ratio relay to close the loop on a fully metered flow ratio system. Both flow meters are of the square-root extracted or linear flow signal type, so effective ratio control can be obtained at any flow rate. By using linearized flow signals throughout this system, it was also

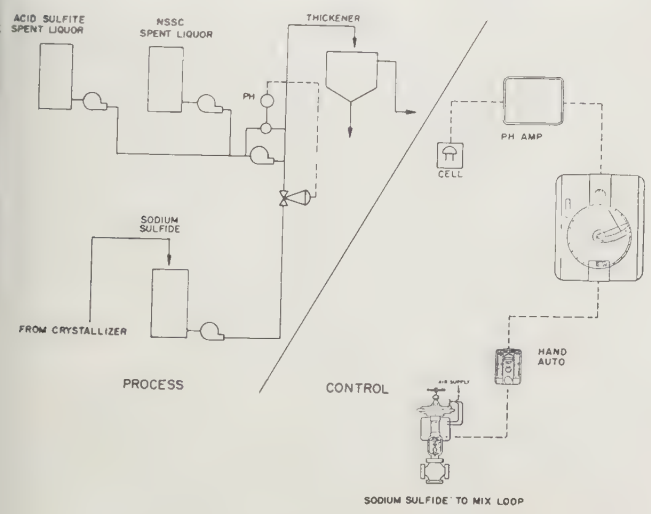


*Fig. 2. Master mixing control*

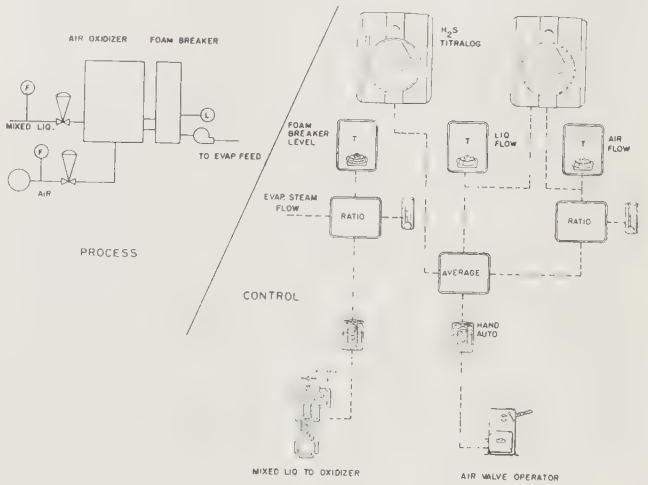


*Fig. 3. Air oxidizer control*

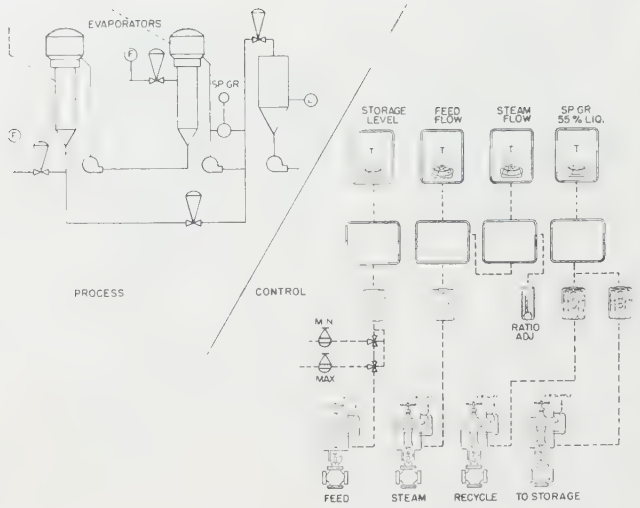


*Fig. 4. Evaporator Control*

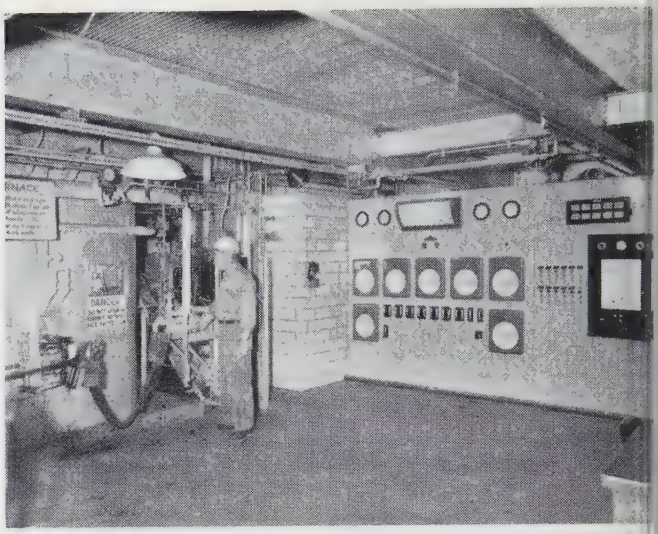

*Fig. 6. Recovery boiler control panel and firing angle*

possible to utilize multipen recording of related variables without complicated chart factors.

Originally it had been planned to use feed liquor density to control the amount of recirculation of heavy liquor to the feed. The problem of measuring the feed liquor density, between 1.0 and 1.1 sp.gr., proved to be an excessive maintenance problem owing to foaming and has since been found unnecessary. Instead, the final product density leaving the multieffect evaporators is monitored, and the recycle is controlled to maintain the desired product density for a given steam to liquor ratio. A lower steam-liquor ratio results in a higher recycle rate and vice versa.

## CONCENTRATOR

Intermediate or 55% liquor is fed to the concentrator at a rate determined by the liquid level in the concentrator body. This is a forced-circulation evaporator unit with considerable storage capacity of heavy liquor making possible a surge capacity between the intermediate storage and the fuel liquor system (Fig. 5). The liquid level control consisted initially of two diaphragm transmitters on the vessel connected to a differential pressure cell calibrated in the range of the liquid level control range. These three components have since been replaced by a single diaphragm type differential pressure cell with the static pressure connection to the opposite side of the diaphragm. This works very satisfactorily but was not available at the time of the original design of this plant.

Steam to the concentrator is proportioned in exactly the same manner as the steam to the multiple-effect evaporators.

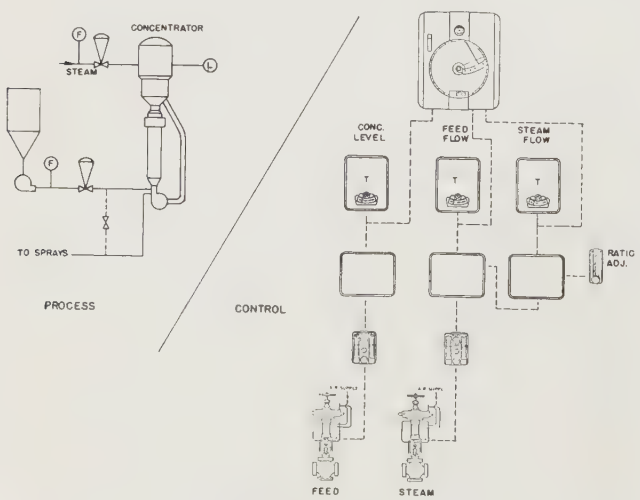


*Fig. 5. Black liquor concentrator control*

The concentration of solids in the evaporator body is measured by the boiling-point rise method using two platinum resistance elements, one inserted into the boiling liquor and one in boiling water at the same pressure. The boiling-point rise is read out in degrees Fahrenheit and data are being gathered for calibration of this value directly into per cent solids. Only infrequently small adjustments are made in the steam-liquor flow ratio control to correct the drift in liquor solids content.

## BOILER

Fuel liquor is pumped through a recirculating loop past the recovery boiler where a metered quantity is passed through a direct contact heater and directly to the oscillating sprays of the Babcock and Wilcox smelter unit (Fig. 6). This unit was originally designed for a capacity of 3100 lb. of solids per hour and has been continually operated at this rating for some time. Our recovery boiler control system is essentially the same as what is now considered standard for kraft recovery units (Fig. 7). The forced circulation evaporator-concentrator substitutes for the cascade evaporator, and fuel liquor solids are controlled as described above rather than by regulating the gas stream through the cascade or through a Venturi scrubber. The boiler exit gas is passed through a three-section air preheater to produce preheated air at a temperature of 350°F. for efficient reduction of the smelt and good combustion efficiency.

The first section of the air heater following the boiler exit

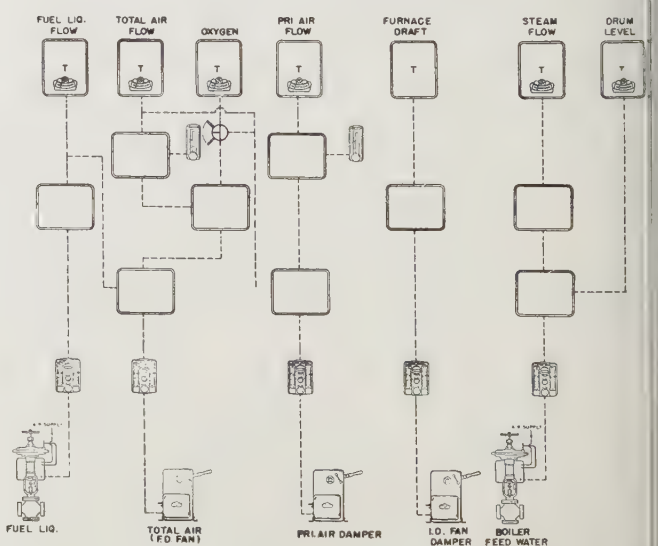


*Fig. 7. Recovery boiler combustion and feed-water control*

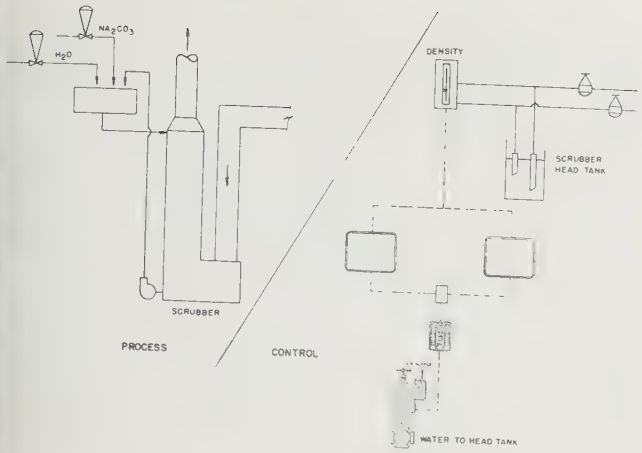


*Fig. 8. $SO_2$ scrubber control*

is a gas cooler and is a substitute for boiler surface in this experimental unit. It is actually a heat waster, but from a capital investment standpoint, it was found cheaper to operate the unit in this manner for 2 years than to purchase the additional boiler surface in this size of unit.

The boiler-smelter unit is a scaled-down recovery boiler with reduced boiler convection surface. It was intended to be used only as a water-cooled smelter on this installation and hence steam generation has not been the primary concern of the designer.

Liquor flow control by means of a magnetic flow meter is the prime control in the recovery boiler. The steam generator floats on the line and pressure is not controlled. Total air flow is proportioned to liquor flow through an adjustable ratio relay and primary air is proportioned to total air in a similar manner. This makes possible a completely variable distribution of primary to total air while maintaining excess air ratio. An oxygen-combustibles analyzer continuously monitors the boiler exit gases and is so equipped that liquor.air ratio can be controlled from the oxygen content in the exit gases for close tolerance of excess air. However, due to the rather wide variations in oxygen content caused by variation in upper furnace combustion, it is felt satisfactory to ratio air to liquor to maintain more stable reducing conditions in the lower furnace reaction. The oxygen recorder is invaluable in maintaining good overall furnace conditions and is worth the nominal maintenance required to keep it in good continuous operation. This one uses a water-cooled, water spray sample probe located in a gas stream at a temperature of about 1100 to 1200°F.

In order to protect the air heater from damage from the high boiler exit temperatues, it is necessary to cool the gas entering

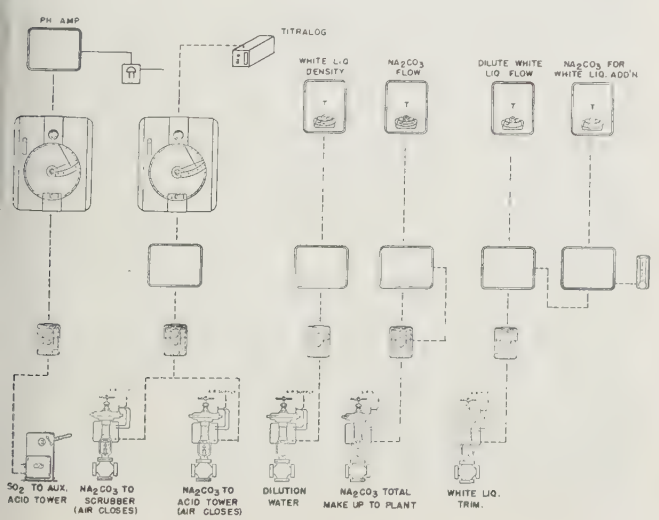


*Fig. 9. $SO_2$ scrubber and white liquor control system*

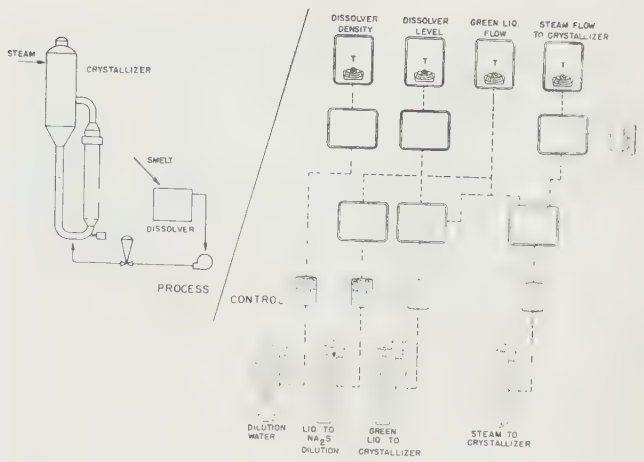


*Fig. 10. Smelt dissolver and crystallizer evaporator control*

the air heater to about 900°F. This is accomplished by a combination water spray and tempering air arrangement controlled by entering gas temperature. The system is effective in protecting the air heater. The spray assemblies, two in number, are standard Y-jet oil burner guns with steam-atomized water doing the cooling.

Other supervisory instruments are included in the boiler complement. (Fig. 6) The feed water control is a standard two-element type which works extremely well in this installation. Boiler steam flow positions the feed water valve through a calibrating relay and this signal is corrected by the boiler drum level.

It is significant to note that the pneumatic signal range of the boiler control, and transmission system is SAMA† 3 to 27 p.s.i. as is also the process control system of this plant. This makes possible complete interchangeability of all relays and parts as well as permitting the interconnection of any part of the boiler system with the rest of the process. It also eliminates operator confusion as they work between various phases of the plant operation.

Following the boiler and heat recovery equipment, the furnace gases consisting of products of combustion, water vapor, and $SO_2$ are passed to the acid scrubber. The $SO_2$ is absorbed here in the first stage of making the white liquor which is returned to the semichemical pulping department. The tower is an upflow slat-packed tower into the top of which is showered sodium carbonate solution and recycled tower liquor. As water is evaporated and the density of the tower liquid in-

† Scientific Apparatus Manufacturers' Association.

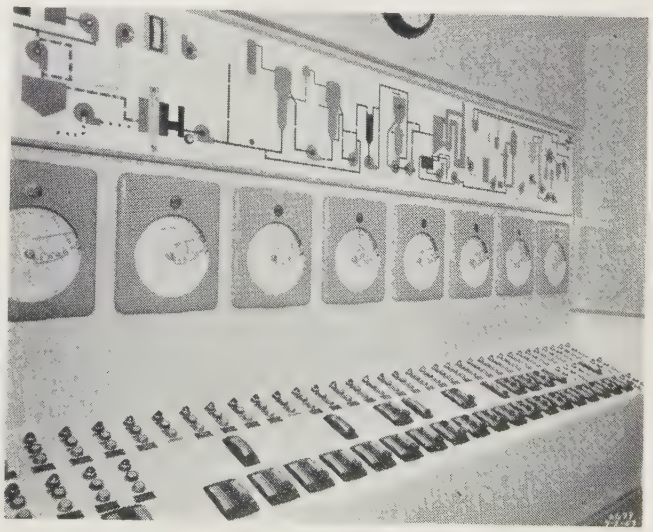

*Fig. 11. Recovery process instrumentation control panel board*

creases, water is added to the head tank under control of a density control loop. This control has an interesting safety feature which prevents the head tank level from running dangerously low, which might permit the tower to run dry in the hot gas stream (Fig. 8).

It works in this manner: the density transmitter is a low differential unit with a double bubble pipe in the head tank. So long as both pipes are covered with liquid, it measures density by changes in differential pressure between the spaced bubble pipes. An increase in density increases the differential produced and the dilution valve opening is increased through normal controller action. The differential range of the transmitter is 4 in. of water for a measuring range of 0.8 to 1.1 sp. gr. When the level in the scrubbing tower head tank drops below the level of the top bubble prove, the transmitter functions as a level measuring device with a 4-in. range. Further drop in level produces an increase in water flow which maintains a safe liquid head over the tower packing.

The remaining instrumentation associated with the $SO_2$ scrubbing tower involves the makeup of white liquor to the semichemical pulping department (Fig. 9). The tower effluent is passed through a small enriching tower where $SO_2$ gas is admitted to lower the pH to a controlled value. The pH controller regulates a damper in the $SO_2$ gas pipeline from the acid plant.

Filtered tower effluent liquor is pumped to a density controlled dilution tank where water is added to bring the liquor to proper strength. Through an over-flow, the dilute white liquor is ratioed to sodium carbonate to produce the proper ratio of sulfite to bisulfite in the white liquor. These flows are metered by square root extracted flow meters and the ratio adjustable by varying the slope of input-output signal on the ratio relay.

The total sodium carbonate makeup is metered and controlled to match the plant makeup requirements. When all the liquor cannot be made in the recovery scrubbing tower, the additional $SO_2$ is absorbed in the enriching tower. Thus a balance is obtained between semichemical requirements, recovery, and acid makeup.

The Titralog shown in the scrubber effluent gas stream monitors for $SO_2$ gas. When the concentration exceeds 300 p.p.m., the sodium carbonate solution flow is increased to pick up the $SO_2$ in the tower. This "sentinel" protects against air pollution and sulfur loss by assuring low sulfur in the tower effluent gas stream and complete absorption in the tower.

### CRYSTALLIZER-EVAPORATOR

Smelt from the bottom of the boiler furnace spouts into the smelt dissolver in which the green liquor is density-controlled by a bubble pipe transmitter-control loop (Fig. 10). We actually consider this a part of the salt recovery system since the feed to the crystallizer is produced here. The level of the dissolver controls the rate of feed to the crystallizer and the dissolver serves as surge capacity for variations in smelt production from the furnace.

The green liquor flow is metered to the crystallizer and steam flow is proportioned to this as a fully metered flow ratio-controlled system. The ratio control is especially critical during startup of the system and steaming of the crystallizer must be watched to govern the formation of crystal structure. This system works quite well in handling the variations in throughput while maintaining stable crystallizer operations.

### PANEL BOARD

The choice and arrangement of a panel board were left until the latter stages in the engineering of this job. After the system engineering was complete, several layouts of recorders and control stations were tried. The semigraphic panel shown here in Fig. 11 was chosen, and we think it has served best the need for process graphic and functional layout. This panel was fabricated in our own sheet metal shop and was tubed and wired by our maintenance staff.

The panel not only serves as a mounting for all the controllers, recorders, and electrical control stations but centralizes the operation of a complete and complex chemical plant. It is a good example of the advancement taking place in centralized control and instrumentation in our industry as a whole and particularly in the recovery processes.

### SUMMARY


1. Pilot plant design requires the utmost in flexibility of design, especially in the instrumentation and control selection.
2. Usually more instrumentation is applied than may be required in a final commercial installation. This is to provide essential data for design of larger operating units.
3. Pilot plant devices should be adaptable to full-scale use, if possible.
4. In all cases of flow metering, uniform chart scale presentation is a most desirable feature.
5. Multipen recording is useful in presenting related data in the same coordinates of time and amplitude dimensions.
6. Panel arrangements that are functional as well as graphic contribute to operator adaptability.


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# Paper Machine Broke Handling


R. D. OWEN


Those of the paper industry acquainted with the development of high-speed paper machines will agree that handling the broke produced during breakdowns, threading operations, or off-quality runs is a critical problem.

To limit the scope of the subject let us discuss the material handling aspects of wet and dry broke only in the machine-room, where a high quality book sheet is produced in quantities of 200 to 300 tons per day at rates up to 2000 f.p.m.

Different grades, different quality, different pulp all add variations that can be approached in the same general manner.

### BROKE HANDLING OF THE PAST

Although we are interested in how some of the mills are handling broke on their new machines, and what can be expected as to future developments in equipment, for just a moment consider how, or why, the problem developed.

Historically, broke systems in earlier days were of little concern; total effort was devoted to developing paper machines to produce a saleable product for an infant market.

Concern for smooth machine operation resulted in equipment improvement which automatically tended toward reduction in overall percentage of broke, but the slow speeds of early rotary machines never produced more broke than could easily be manhandled away by an operator.

This, then, was the era of the broke baskets that made endless trips to the beater room.

Management soon realized the cost incident to such handling was high and designers commenced working on the theory that repulpers should be located close to the source of


R. D. Owen, P. H. Glatfelter Co., Spring Grove, Pa.

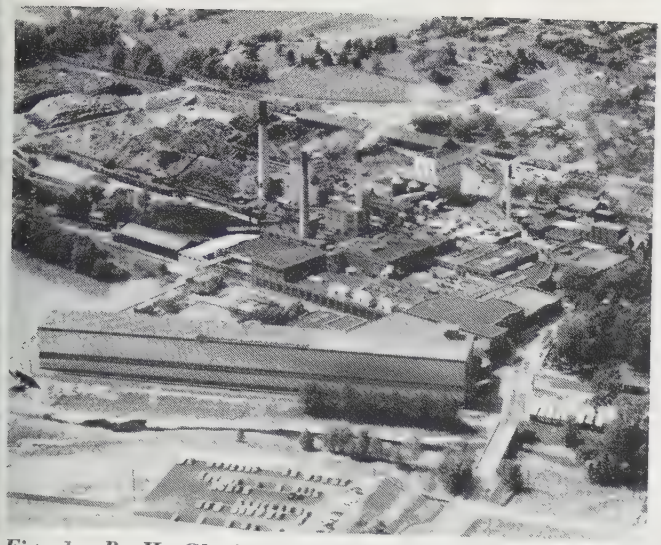

*Fig. 1. P. H. Glatfelter Co. mill at Spring Grove, Pa.* No. 7 machine building in foreground with older machine buildings and pulp mill behind.

the broke such as dryer pits, calender stacks, and trim discharges. First it was a matter of a relatively dry pulping operation to fill broke bins for storage and then came repulpers maintaining low consistencies which allowed pumping as a mode of conveying material to the beaters.

Each improvement in handling the broke thus far was motivated by labor cost considerations, but with expanding markets and resultant higher tonnage machines, a more dominant factor became the major concern. Now it was worth higher costs to insure quick removal of the sheet during a break to prevent a machine shutdown for clean out.

Acceptance of a standard building design in which basements were created for placing a repulper beneath the machine satisfied the papermakers and made use of gravity discharges directly into the pulping equipment. For some time this design has been followed, as proven by the many present day installations, until mill designers realized the benefits of conveyors, fork trucks, and other advancements in the field of material handling. Such equipment was not adaptable to the confines of a basement, dictating a recent trend to elevating the machine track, allowing free access beneath all sections of the paper machine.

Thus, the handling problem that was little more than incidental during the embryonic development of paper machines, has grown to a point where full, serious consideration and study is required for optimum results.

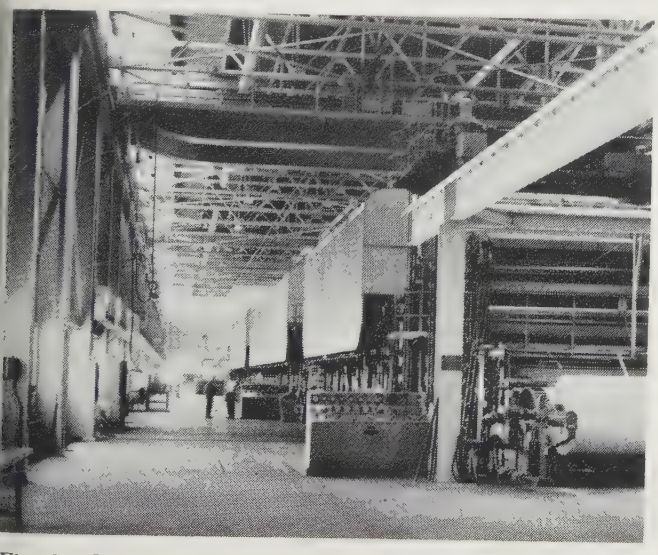

*Fig. 2. No. 7 machine room, 600 ft. long with easy crane access to any location*

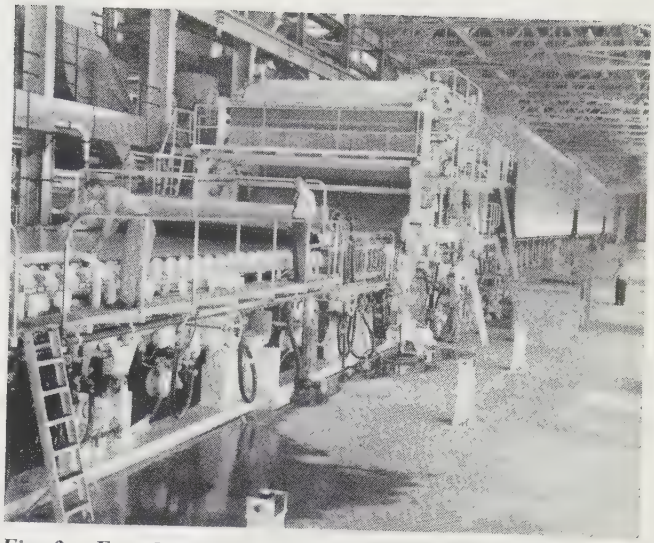

*Fig. 3. Fourdrinier and press section of the 188-in. Rice Barton machine*

## THE NO. 7 GLATFELTER MACHINE

All of the men involved in the designing and planning for the no. 7 paper machine at the P. H. Glatfelter Co. in Spring Grove, Pa., were cognizant of the gradual growth of importance in broke handling methods and an attempt was made to include all the latest advancements, in the new installation.

A description of the machine in general, together with photographs taken recently will indicate the scope of the $12,500,000 expansion started in 1954 and completed, with paper on the reel, November, 1956.

Physical limitations adjacent to the six operating paper machines prevented expansion in the immediate area, necessitating the selection of a site, although close to the existing mill, entirely separate as to building, utilities, and shipping facilities. While this increased costs somewhat, it allowed freedom in building design and internal material flow. It provided a complete break from the old to the new since the last previous machine had been installed in 1930. (Fig. 1)

The new building, constructed of insulated aluminum panels, plastic illumination bands, and brick, presents a very modern appearance and houses the complete paper mill including stock preparation equipment, proportioning system, paper machine, finishing, storing and shipping facilities. Maximum use was made of available land while maintaining a convenient and flexible space relationship within the buildings 600 ft. in length.

The machine itself had many "firsts" for equipment of its

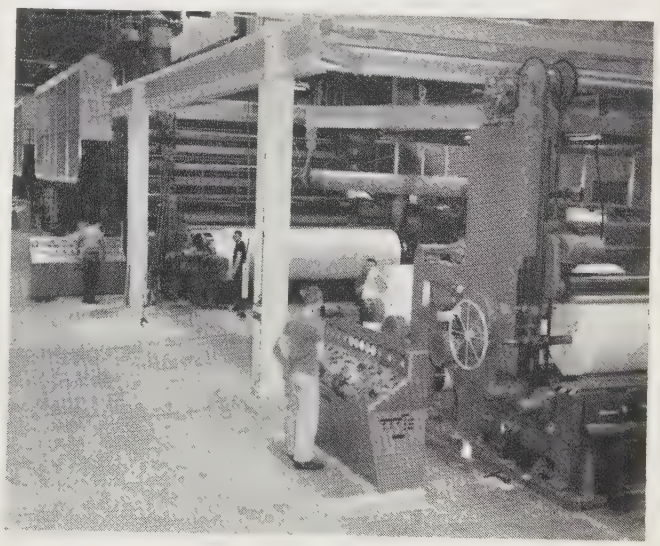

*Fig. 4. Machine winder, reel crane and reel*

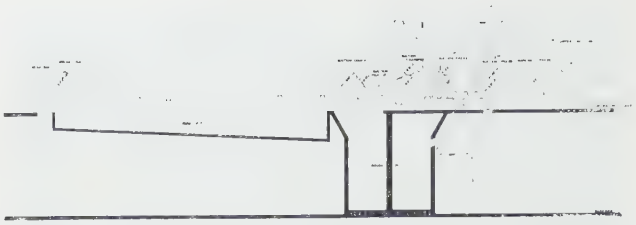

*Fig. 5. Line diagram of the wet end of the machine*

type and has served as a model for many mills built since the time of its installation. Present operations have surpassed a 200 ton per day rate and speeds over 1500 f.p.m. and there is a potential capacity of 400 tons per day or 2000 f.p.m. with certain required changes.

To further understand the size of this undertaking let us look at a few photographs taken in the building, first, a view looking down the tending aisle. (Fig. 2)

Now—a look at the 188-in. fourdrinier and the press section which includes suction pickup, transfer, 1st press, 2nd press, and marking press. (Fig. 3)

Next is a view of the machine winder, capable of rewinding at 5000 f.p.m., and a view down the drive side indicates it is a differential drive machine powered by a 1850 hp., 600 p.s.i. noncondensing turbine. (Fig. 4)

## BROKE HANDLING OBJECTIVES

In selecting and laying out the conveying equipment for broke handling on this machine there were three distinct objectives in mind. First, and always important with a competitive market, was getting satisfactory labor saving equipment that would result in low broke handling costs. Second, was quick efficient disposal of the broke, partly to prevent any production interruption but also to prevent the accumulation of a fire hazard. The third requirement was for a broke system that provided both safe working conditions and permitted good housekeeping; a point on which the P. H. Glatfelter Co. has always been insistent.

Now let us look at a line diagram of the machine so that we can see where the various broke removal points occur and generally how the equipment is located. (Figs. 5 & 6)

Note first the location of the machine, the use of elevated base plates which leaves the basement wide open for material handling as has previously been pointed out.

### *Wet Broke Handling*

A conventional design was followed for handling fourdrinier broke by discharging directly into a 2-ton capacity couch pit. Running perpendicular to the centerline of the machine the chest is erected with a midfeather and 48 in. horizontal adjustable pitch agitator. This chest also receives all wet end broke from the press section, being pumped back to the stock proportioning system for use in the machine furnish.

Removal from the first press was accomplished by doctoring into a 16 in. stainless steel screw conveyor located parallel to and directly behind the 28 in. microrok top roll. This conveyor, rotating at 250 r.p.m. was designed for handling broke of 5 to 6% consistency at a rate of 220 ton per day. A 2-in. diam. spray pipe with 40 nozzles discharged directly onto the screw to aid in removal and start the repulping process.

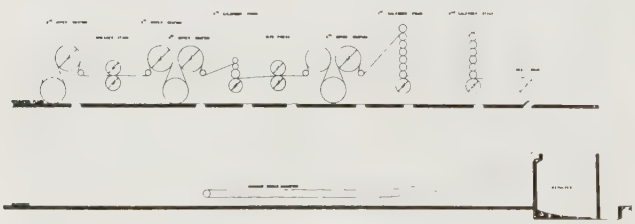

*Fig. 6. Line diagram of the dry end of the machine*

Additional repulping was obtained in a second screw conveyor which was located at the backside of the machine to handle the broke 10 ft. in the machine direction, discharging directly into the couch pit.

Problems at the first press were encountered from the very beginning when the self-dumping doctor failed to remove the wet sheet at a constant rate, causing slugs of broke to enter the screw conveyor. This action, combined with build-up behind the conveyor hangers, caused overloading, plugging and stalling of the screw itself.

Failure to dispose of all broke at this point was critical since, with the suction pickup on the machine—it had to be kept clear until a tail could be passed through the 4th dryer section and into the next broke handling system. Since the 1st press broke removal equipment did not function properly at speeds approaching 1000 f.p.m. a change was imperative to make possible the production rate for which the machine was designed.

The doctor was relocated to a point as far back on the top press roll as possible to make full use of the velocity of discharge, thus carrying broke directly into the conveyor and minimizing build-up on the blade itself. Air jets were installed where possible to aid in maintaining continuous discharge.

The main screw conveyor was removed at this time, substituting a 24-in. belt conveyor which has been standard on paper machines for some time.

Occasional difficulties arise with the screw conveyor on the back side but it has been retained for its repulping action. Since original thinking had been to do most of the repulping before discharge into the couch the agitation in the couch pit was designed for normal blending and mixing only. Herein lies some difficulty for the future since we believe higher speeds will require more pulping which can be obtained by the addition of a shredder at the discharge of the belt or conversion of the couch pit to a horizontal multiblade pulper. The second alternative, while more costly, would allow drawing down the couch to a low level during change-offs where as now a relatively higher level is required to obtain maximum effort of the present agitator.

At the 2nd press the doctoring problems were not so great since the removal is from the bottom roll, this being an inverse press. The original installation included a 16-in. stainless steel, screw conveyor beneath this roll, a duplicate of the 1st press installation. After personnel became familiar with sheet passing this screw conveyor was found to be unnecessary and was removed completely.

### *Dry Broke Handling*

Material handling equipment for disposing of dry broke was

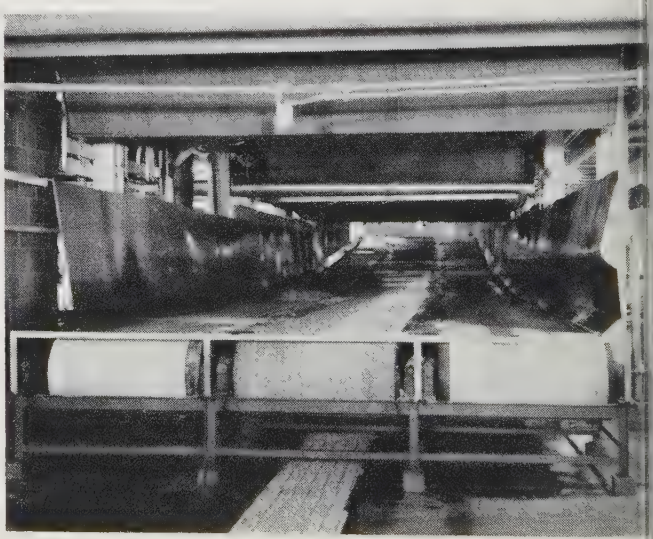

*Fig. 7. Machine broke conveyor viewed from the feed end beneath the size press*

installed only under the final drying stages of the machine since broke discharge from the early dryer sections was expected to be minimal. The small accumulations from these sections fall directly to the basement floor, to be collected and manually placed on the machine broke conveyor which starts beneath the 4th dryer section. (Fig. 7)

After running in the machine direction beneath all sections from the 4th dryer section to the reel, the machine broke conveyor discharges into a Brokemaster. The conveyor consists of three 4 ft. wide belts sliding on a pan, full width between the 15 ft. girt lines of the machine. Each belt is centered by individual tail pulleys and driven at the discharge end by a two-speed motor through a common head pulley shaft. Portions of the broke not supported directly on the belt are dragged along the pan by the remainder of the sheet.

A distinct disadvantage in this type of conveyor lies in its inability to insure positive movement of material. The handling is dependent upon frictional resistance between the dry broke and belt which will vary with condition of the belt surface and weight of paper involved. An additional disadvantage was encountered in this particular installation in that the final 40 ft. of conveyor had to be inclined to reach a proper height for discharging into the Brokemaster. A normal slippage problem in the horizontal sections of the conveyor was sharply increased where the sheet entered the incline and greater drag along the exposed pan surface existed.

Several steps have been taken to reduce this slippage and thereby prevent excessive pile-up on the conveyor. First, replacement belts were purchased and installed which had top friction surfaces. Second, a fine water mist was installed over each tail pulley to moisten the belt prior to receiving any broke discharge from the machine above. In turn such action was believed to moisten the paper slightly, causing adherance to the belt. Third, and last, was the installation of air jets at the edge of the conveyor, pointed in the machine direction to provide additional movement of the sheet toward the Brokemaster.

The first two steps above proved unsatisfactory when wet fibers created build-up in the friction segmentations of the belt surfaces. This process produced a very smooth carrying surface, due primarily to inability of any scraper to remove the build-up sufficiently. The third aid, use of air jets, provided minor impetus to the broke but nozzle installation at intervals along the full 100 ft. conveyor length would have severely taxed the mill air supply.

The greatest single improvement in this 100-ft. conveyor was recently made by altering the incline of the pan. As originally installed, the first 53 ft. were in a horizontal plane, the remainder, in a 200-ft. radius arc to attain the necessary discharge height. This required height was reduced by lowering the rear wall of the pulper to a minimum and the conveyor was altered by using a straight inclined plane, doing away with the arc that caused so much build-up of the dry broke.

Another change that is now being considered is speeding up the conveyor since the present 500 f.p.m. is underdesigned for machine speeds of 1500 and 660 f.p.m. can be easily obtained.

A major drawback in using any machine broke conveyor, which transports dry broke at full machine width, occurs at the discharge end where billowing of the sheet is likely to occur. All the showers and vortices in the pulper prove unsatisfactory substitutes for a positive method of obtaining quick sheet submergence and preventing formation of a floating ball.

## REPULPER

Although the repulper is considered a segment of the broke handling system it also falls in the field of defibering, a broad field of study in itself. It is merely mentioned here to point out the importance of having a centralized deposit point for dry broke, similar to the couch pit that normally exists for accumulation of wet broke. All dry broke from both the machine and finishing departments is channeled to this point where it is reprocessed for use in the machine furnish.

It should be pointed out the repulper on the Glatfelter machine is designed for defibering the full sheet to 4% consistency at full machine production rate; automatic controls maintaining chest level, consistency and pumping rate to broke storage chests as necessary.

Incidentally, there are two broke storage chests, in the stock prep area, which hold 9 tons of 4% broke pulp.

Each repulper manufacturer has his own sales points and a claim to surpass his competitor. I do not propose to make any comparisons at this time but there is one recommendation that could save money and headaches for anyone contemplating an installation. Make the pulper tank or chest of stainless steel and stay away from tile construction; especially if finishing room broke is also involved. Any foreign metal such as nuts, bolts, wedges, items that are not supposed to but always will enter the system, create expensive damage in a tile chest. The high degree of agitation and lengthy time between clean-outs incident to automatic equipment of today, magnify the foreign metal problem immensely.

One additional advantage, in using metal construction is the ease of making alterations to baffles, shower braces, etc., by welding; retiling takes time.

## BROKE HANDLING OF THE FUTURE

Having traced the development or rise of broke handling problems, and having taken a quick look at one of the more recent systems installed on a paper machine, the logical question arises—"Where do we go from here?"

There is no question that present day methods have serious limitations; the inadequacy of broke handling and processing equipment which has been offered the industry thus far must be improved upon by paper mill equipment manufacturers. The industry is presently building and operating book paper machines in the 1500 to 2000 f.p.m. range; but production speeds will not stop there and we need better broke handling facilities.

Recent philosophy has simply been to build larger repulpers, apply more and more horsepower, and concentrate on defibering full machine production for immediate return to the furnish in a headbox-ready condition.

There is no denying that broke must be removed from the machine at full machine rate, but the state in which it is removed is of little concern to the machine operators; they just want it out of their way.

A normally operating paper machine producing 10% broke will most likely be capable of handling 20 to 30% broke in its furnish. When a break occurs, on the other hand, broke is produced at the full production rate of the machine. It does not seem logical to install, under the machine, equipment capable of preparing this broke for furnish at a rate approximately 3 to 5 times the rate at which it will be fed back into the system.

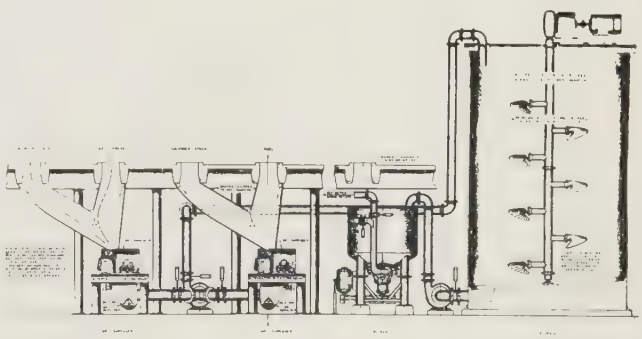

*Fig. 8. Possible design for future broke equipment at the dry end of a paper machine*

# PUMPAGE

**Goulds reports on trends in pulp and paper**

**ON THE BLEACH.** More than one bleach mill has told us their stock and filtrate pumps in stainless steel have been in service for fifteen years or more—without replacement of the original casing. By using standard pumps, most mills avoid the cost of inventorying special pump parts. Spare rotating parts for their chlorine and hypochlorite bleaching pumps are the same as those on standard stainless steel trimmed pumps already in use at most mills. We can usually ship pumps and parts in 316-standard immediately from stock. We pour 317 for chlorine dioxide to order. The right kind of stainless makes the difference in giving you long, low-cost service. Contact your Goulds man for help in making your selection.

**DIGESTER CIRCULATING . . . WHICH PUMP?** Whether circulating in continuous or batch digestors, your pumpage is the same—hot, corrosive, highly abrasive. For best service life and lowest long-run costs you need *all* these: (1) Extra-thick casings with generous corrosion allowances, (2) Water-cooled bearings, (3) Fully open impeller with ejector vanes on back side adjustable externally to compensate for wear, (4) Back pull-out design with spacer coupling for easy dismantling, (5) In and out stuffing box flushing connections. Goulds Model 3138 measures up to these standards. Available with or without spring-loaded bedplates. For detailed bulletin, drop us a line.

**WHEN PUMPS WEAR . . . IS IT EROSION, CORROSION, OR BOTH?** Corrective measures depend on knowing one from the other. In our data section 766.8, you will find a series of photographs that make it easy for you to identify the cause of internal pump damage. A postcard request will bring you your free copy.

## OBSERVATIONS

**ON FIRST COST VS. FINAL COST**

By E. D. Schwandt, Assistant Chief Engineer, Goulds Pumps

The current tight money situation lies behind the closer look at first cost.

First cost is definitely important, but a *true* analysis of pumping costs must also include other cost factors—such as power consumed and maintenance required. In too many cases, the first-cost saving in buying competitive-design equipment is offset within the first year or two of operation by machine downtime and costly repair.

On the basis of our experience with mill installations (including both competitive- and custom-design pumps), we feel replacement, power, and maintenance costs can be minimized by buying first-grade pumps. Experience proves that a quality pump is often the one that is *least expensive in terms of cost per million gallons pumped.*

Whatever the cost considerations—long-term or short-term—let us help you engineer the pump best suited to your job.

Goulds Pumps, Inc., Dept. TA-60, Seneca Falls, N. Y.

**GOULDS PUMPS**


Continuing with this thinking, the solution appears to be a system composed essentially of four units:

1. A conveyor under the machine running continuously, which will positively remove all broke falling into the basement at the rate at which it is produced.
2. A dry or wet chopping machine to reduce broke at the rate at which it is produced to a state in which it can be blown or pumped away from the machine without further treatment.
3. Storage, wet or dry, in which the broke from the machine can be stored for further processing.
4. Pulping and/or refining equipment to further treat the broke to prepare it for use as a portion of the furnish on the machine at the rate at which it will be fed into that furnish.

Some research and pilot plant operation has been accomplished along these lines and one manufacturer is offering a complete installation, which is indicated in Fig. 8.

There are many variations possible but in this scheme there is no conveyor beneath the machine, individual dry shredders are located at floor discharge points to accept the sheet directly from the machine. This is one big step toward quick positive removal, doing away with the machine conveyor that can cause considerable trouble, but we have to admit this has higher initial charges.

The second advantage of this system is storage of the broke at high consistencies to reduce capacity requirements in chests and the ability to withdraw required amounts to the pulper for actual defibering.

This is the point that is important—defibering at the rate broke is used, not at the rate it is produced.

A step further that is entirely possible but not indicated in this layout is using an airvayor system to handle dry patches straight from the shredder to storage, again reducing the capacity requirements for broke storage.


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**Fifteenth Engineering Conference**

**Robert Meyer Hotel,**

**Jacksonville, Fla.,**

**Oct 24–28, 1960**

# UNITED STATES PATENTS ON PAPERMAKING

*Fourth Quarter, 1959* — *Compiled by The Institute of Paper Chemistry*

THE following list of United States patents has been compiled from the current numbers of the Official Gazette of the United States Patent Office. Because, as a rule, only one claim is published in the gazette, it is not claimed that the list is complete; also, it is possible that the list may contain some patents that do not apply specifically to pulp and paper manufacture. Copies of any of the following patents may be obtained from the United States Patent Office, Washington 25, D. C., by sending twenty-five cents for each patent desired. Or, those desiring the patents on *microcards* should write to The Institute of Paper Chemistry, Appleton, Wis.

### Oct. 6, 1959

Agronin, Tany. Paper machinery. U. S. patent, 2,907,499. Filed April 22, 1957. 4 claims. Assigned to Pandia, Inc. [Cl. 222-272.] A rotary valve is provided for feeding wood chips into a rotary digester.

Allen, John M. Clothespin loading machine. U. S. patent 2,907,159. Filed June 24, 1958. 10 claims. Assigned to Penley Bros. [Cl. 53-154.] Clothespins are loaded into cartons.

Auer, László. Clear and pigmented multicomponent oil-in-water resin emulsion textile decorating compositions and process for preparing same. U. S. patent 2,907,720. Filed July 23, 1956. 15 claims. Assigned to J. R. Geigy, S. A. [Cl. 260-6.] Methylcellulose and carboxymethylcellulose are used in a textile-printing composition.

Auer, László. Clear and pigmented oil-in-water resin emulsions containing pentaerythritol alkyd resins. U. S. patent 2,907,721. Filed June 14, 1954. 15 claims. Assigned to J. R. Geigy, S. A. [Cl. 260-7.5.] Tall oil and methylcellulose are used in a textile printing composition.

Batchelder, James W. Flow control mechanism for counting packaging apparatus and electric circuitry therefor. U. S. patent 2,907,154. Filed June 25, 1957. 18 claims. [Cl. 53-59.] Improved feeding and counting control is provided in a machine for packaging screws and bolts and the like.

Bemporad, Cino. Web edge position signal generator. U. S. patent 2,907,337. Filed July 23, 1956. 5 claims. Assigned to Regulator, S. R. L. [Cl. 137-83.]

Bermingham, Arthur T., Jr., and Holthaus, Glenn P. Return envelope mailing piece. U. S. patent 2,907,514. Filed Oct. 27, 1955. 7 claims. Assigned to Columbia Envelope Co. [Cl. 229-73.]

Bikales, Norbert M., Gruber, Arnold H., and Rapoport, Lorence. Cyanoethylation of cellulose. U. S. patent 2,907,625. Filed March 8, 1956. 3 claims. Assigned to American Cyanamid Co. [Cl. 8-120.]

Chamberlin, Charles E. Bottle carrier crate. U. S. patent 2,907,509. Filed Feb. 27, 1956. 3 claims. Assigned to Container Corp. of America. [Cl. 229-15.]

Draper, John H., Jr. Method of making paper-makers wet felt. U. S. patent 2,907,093. Filed June 8, 1956. 6 claims. Assigned to Draper Bros. Co. [Cl. 28-72.] A separable joint construction is provided.

Drentlaw, Leonard J. Carton holders. U. S. patent 2,907,493. Filed April 8, 1957. 1 claim. Assigned 1/3 to P. R. Griebler and 1/3 to Wayne Westgor. [Cl. 220-85.] A gable-top paperboard milk carton is provided with a handled device for supporting the carton during use.

Dyar, Robert L. Grinding disks. U. S. patent 2,907,146. Filed May 21, 1957. 3 claims. Assigned to Milwaukee Motive Mfg. Co. [Cl. 51-195.] Improved flexibility is provided in an abrasive disk comprising abrasive material adhered to a fibrous backing.

Eichel, Herman J. Adhesive tape containing pressure-rupturable capsules. U. S. patent 2,907,682. Filed May 28, 1958. 4 claims. Assigned to The National Cash Register Co. [Cl. 117-122.]

Engels, Kaspar. Mixing apparatus. U. S. patent 2,907,555. Filed April 6, 1955. 1 claim. Assigned to Draiswerke G.m.b.H. [Cl. 259-9.] The apparatus mixes chips and resin for making wood-particle board.

Engleson, Harry E., and Sramek, Elmer D. Article transfer mechanism. U. S. patent 2,907,155. Filed April 25, 1956. 13 claims. Assigned to F. B. Redington Co. [Cl. 53-63.] Cylindrical rolls of candy are transferred into a carton.

Friedman, Aaron, Lurie, Daniel, and Dale, Sheldon. Bagging machine. U. S. patent 2,907,160. Filed July 12, 1957. 11 claims. Assigned to Joe Lowe Corp. [Cl. 53-189.] Frozen confections with stick handles are inserted into bags.

Grieve, George T. W., and Ripley, Stanley W. Machine for lapping strips of material on electric conductors and other articles. U. S. patent 2,907,164. Filed Nov. 26, 1956. 1 claim. Assigned to British Insulated Callender's Cables Ltd. [Cl. 57-13.] Paper tape is spirally wrapped about a cable.

Hall, Elisha W., 2nd, and Paone, Dominick R. Rotary abrasive element. U. S. patent 2,907,145. Filed April 25, 1958. 3 claims. Assigned to F. L. & J. C. Codman Co. [Cl. 51-193.5.] A number of sandpaper sheets are affixed in slots about the periphery of a heavy paperboard disk.

Hartmann, Waldemar. Method of aggregating carbonaceous material. U. S. patent 2,907,645. Filed Jan. 22, 1957. 1 claim. [Cl. 44-16.] Spent sulfite liquor is used in aggregating coal dust, fly ash, and the like.

Hensgen, Bernard T., Bonami, Ernest, and Clements, Ogden A. Method and machine for use in packaging of bacon or the like. U. S. patent 2,907,152. Filed Dec. 20, 1956. 21 claims. Assigned to Swift & Co. [Cl. 53-35.]

Hornbostel, Lloyd, and Beachler, Edward D. Air bleed press with hot gas drying. U. S. patent 2,907,690. Filed Feb. 6, 1958. 5 claims. Assigned to Beloit Iron Works. [Cl. 162-206.]

Johnson, Elmer S. Process of calcining gypsum. U. S. patent 2,907,667. Filed March 30, 1956. 13 claims. Assigned to United States Gypsum Co. [Cl. 106-111.] Carboxymethylcellulose is used.

Labrozzi, Anthony F., and D'Orazio, Peter J. Packaging apparatus. U. S. patent 2,907,158. Filed Feb. 9, 1956. 8 claims. Assigned to Intern. Resistance Co. [Cl. 53-126.] Electrical components such as resistors are arranged in orderly fashion in a carton.

Leone, Salvatore J. Shipping and dispensing cartons. U. S. patent 2,907,512. Filed April 8, 1958. 3 claims. Assigned to The New Haven Board and Carton Co. [Cl. 229-17.] A lower part of the carton opens and swings out to form a dispensing trough.

Linder, Bertram N., and Young, Nathan H. Collapsible wardrobe cross bar. U. S. patent 2,907,452. Filed May 14, 1956. 1 claim. Assigned to Linder Bros., Inc. [Cl. 206-7.] An improved hanger bar is provided in a paperboard container for shipping hangered garments.

Madeline, Raymonde G., and Pathus-Labour, Jean F. Fireproofing textiles and like. U. S. patent 2,907,683. Filed Feb. 8, 1954. 2 claims. Assigned to Firma Deutsche Erdoel A.G. [Cl. 117-136.] Paper and textiles are fireproofed by precipitating calcium alginate on the fibers.

Meiler, John G., and Johnson, Earl A. N. Process for producing hard board. U. S. patent 2,907,071. Filed Aug. 11, 1955. 11 claims. Assigned to Rayonier, Inc. [Cl. 18-47.5.]

Millman, Nathan, and Whitley, James B. Apparatus and method for treatment of clay. U. S. patent 2,907,666. Filed July 6, 1956. Oct. 6, 1959. 2 claims. Assigned to J. M. Huber Corp. [Cl. 106-72.] Kaolin is prepared for use in papermaking.

Nies, Brainard W., and Johnson, Elmer S. Calcination of gypsum. U. S. patent 2,907,668. Filed March 30, 1956. 9 claims. Assigned to United States Gypsum Co. [Cl. 106-111.] Carboxymethylcellulose is used.

Owens, Donald L. Machine for setting up collapsed paperboard boxes. U. S. patent 2,907,252. Filed Sept. 23, 1955. 17 claims. [Cl. 93-49.]

Pride, George H. Container for granular materials. U. S. patent 2,907,508. Filed April 16, 1954. 1 claim. Assigned to Acme Steel Co. [Cl. 229-4.5.] A shipping container for sugar is assembled from metal plates and a paperboard element.

Robbins, Albert A. Method of forming a cooling package. U. S. patent 2,907,173. Filed May 4, 1956. 4 claims. Assigned to Kwik-Kold of America, Inc. [Cl. 62-4.] A refrigerating pack includes blotting paper.

Romine, James W. Method of and apparatus for wrapping packages. U. S. patent 2,907,157. Filed Dec. 16, 1955. 11

claims. Assigned to Greening Nursery Co. [Cl. 53-124.] A thermoplastic-coated paper is heat-sealed about the roots of a plant.

Rosso, Victor Del. Rotary feeding and timing device. U. S. patent 2,907,443. Filed Sept. 10, 1956. 6 claims. Assigned to Hi-Speed Checkweigher Co., Inc. [Cl. 198-34.] The device provided feeds packages at spaced intervals for subsequent treatment.

Saidel, William R. Reclosable cartons. U. S. patent 2,907,511. Filed Nov. 13, 1956. 6 claims. Assigned to Foil Cartons, Inc. [Cl. 229-17.] Improved dispensing means are provided in a carton which may be reclosed in a relatively sealed condition.

Seaman, Stewart E. Apparatus for forming a fibrous web from a liquid suspension. U. S. patent 2,907,388. Filed June 26, 1957. 2 claims. [Cl. 162-305.] A board machine press section comprises two smooth rolls forming a nip with a third roll having surface grooves opening into the hollow interior of the roll.

Staicopoulos, Dimitrios N. Composition comprising methyl methacrylate polymer, nitrocellulose, reaction product of a bisphenol and dicarboxylic acid and solvent, process for preparing same and article coated therewith. U. S. patent 2,907,722. Filed March 11, 1957. 8 claims. Assigned to E. I. du Pont de Nemours and Co. [Cl. 260-17.] This is an auto body lacquer.

Thiolat, Robert M. Cardboard boxes and like. U. S. patent 2,907,513. Filed June 20, 1957. 2 claims. [Cl. 229-31.] A paperboard box with partially telescoping separate lid is provided with means for locking the lid to the box.

Toles, Burton. Packaging apparatus. U. S. patent 2,907,153. Filed Nov. 25, 1958. 8 claims. [Cl. 53-55.] Bags of flour are baled into a single outer container and the container sealed.

Vines, Oscar L. Carton. U. S. patent 2,907,510. Filed June 14, 1955. 4 claims. Assigned to Continental Paper Co. [Cl. 229-16.] Improved tongue-and-slot means are provided to interlock various panels of a berry box.

Weiss, Bernard W. Combination match and cigarette package. U. S. patent 2,907,453. Filed Oct. 20, 1958. 3 claims. [Cl. 206-48.]

### Oct. 13, 1959

Aelony, David. Thermoplastic adhesives of polyamide resins and polybasic aliphatic acids. U. S. patent 2,908,584. Filed Jan. 11, 1956. 6 claims. Assigned to General Mills, Inc. [Cl. 106-287.] The adhesives are for use on paper or for coating paper.

Braendle, H. A., and Heller, G. L. Beaded carbon black. U. S. patent 2,908,586. Filed Feb. 6, 1957. 4 claims. Assigned to Columbian Carbon Co. [Cl. 106-307.] Rosin is used.

Brodie, George R. Web associater and folder. U. S. patent 2,908,494. Filed May 15, 1957. 4 claims. Assigned to Fred'k H. Levey Co., Inc. [Cl. 270-41.] Improvements are made in a slitting and folding mechanism for handling the output of a web-fed publication printing press.

Bryant, James L. Vapor confining air curtain for paper machines. U. S. patent 2,908,212. Filed Sept. 30, 1957. 2 claims. Assigned to Ross Eng. of Canada, Ltd. [Cl. 98-36.]

Buckman, Kenneth E. Filter elements. U. S. patent 2,908,350. Filed Dec. 8, 1954. 1 claim. Assigned to General Motors Corp. [Cl. 183-44.] Resin-impregnated paper is deformed to provide ribs in the paper, and the paper is folded to form an air filter for internal combustion engines.

Cisney, Merle E., and Goheen, David W. Preparing organic sulfides. U. S. patent 2,908,716. Filed April 8, 1957. 15 claims. Assigned to Crown Zellerbach Corp. [Cl. 260-609.] Dimethyl sulfide is prepared from spent pulping liquors.

Clauss, Robert W. Automatic package marking device. U. S. patent 2,908,219. Filed July 19, 1954. 29 claims. Assigned to National Dairy Prods. Corp. [Cl. 101-44.] Indicia are automatically printed on the lids of food containers.

Clemons, Dale R. Methods of making electrical capacitors. U. S. patent 2,908,067. Filed April 9, 1956. 4 claims. Assigned to Western Electric Co., Inc. [Cl. 29-52.42.]

Enos, Joseph, Jr. Packages and packing methods. U. S. patent 2,908,121. Filed Dec. 4, 1956. 2 claims. Assigned to California Wheeling Machine Prods. Co. [Cl. 53-3.] Pipe fittings and the like are packed into an open-end sleeve secured with adhesive tape.

Evans, Melvin E. Multiplying device. U. S. patent 2,908,439. Filed Nov. 19, 1956. 1 claim. [Cl. 235-88.] Several superposed diecut paperboard disks form a device for solving simple problems in arithmetic multiplication.

Fairest, Derek H., and Banks, Sydney E. Labelling machines. U. S. patent 2,908,414. Filed Feb. 5, 1958. 10 claims. Assigned to Morgan Fairest Ltd. [Cl. 216-54.]

Fleener, Austin E. Tag dispenser. U. S. patent 2,908,435. Filed Sept. 30, 1954. 9 claims. Assigned 1/6 to Warren H. F. Schmieding, and 1/6 to Palmer Fultz. [Cl. 225-32.] Tags are dispensed from a supply stack in zigzag folded strip form and string ties are attached to each tag.

Haines, Robert M., and Walsh, John W. Process for the preparation of oxidized microcrystalline waxes of increased hardness. U. S. patent 2,908,702. Filed July 30, 1957. 7 claims. Assigned to The Pure Oil Co. [Cl. 260-452.]

Hellberg, Gustav S. Method and means for the perforation of paper and the like. U. S. patent 2,908,201. Filed Feb. 6, 1956. 13 claims. Assigned to Aktiebolaget Produktions-Service. [Cl. 90-11.]

Hinz, Otto C. Improved industrial woven wire belts. U. S. patent 2,908,065. Filed Aug. 13, 1953. 2 claims. [Cl. 28-78.] An improved joint construction in a fourdrinier-type wire prevents central troughing of the belt during use.

Järund, Harry S. V. Apparatus for automatically packing tetrahedron-shaped packages. U. S. patent 2,908,125. Filed May 13, 1957. 6 claims. [Cl. 53-142.] The containers (of milk) are packed into an outer shipping container.

Keely, Clifford D. Table tilt device for taper. U. S. patent 2,908,497. Filed Dec. 13, 1956. 7 claims. [Cl. 271-62.] An improved sheet feeder for box blanks is provided.

Long, William J. Mechanical apparatus for feeding documents. U. S. patent 2,908,496. Filed May 16, 1957. 6 claims. Assigned to Minneapolis-Honeywell Regulator Co. [Cl. 271-32.]

Lytton, Marion R. Producing all skin viscose rayon. U. S. patent 2,908,581. Filed July 2, 1957. (Divided; original Nov. 3, 1954.) 4 claims. Assigned to American Viscose Corp. [Cl. 106-165.] The coagulation modifier is an alkylene oxide adduct of a *p*-aliphatic aniline.

Lytton, Marion R. Production of all skin rayon. U. S. patent 2,908,582. Filed July 2, 1957. (Divided; original June 29, 1955.) 5 claims. Assigned to American Viscose Corp. [Cl. 106-165.] The coagulation modifier is an alkylene oxide adduct of *p,p'*-diphenol.

Lytton, Marion R., and Mueller, George F. Method of producing viscose rayon. U. S. patent 2,908,583. Filed July 2, 1957. (Divided; original Nov. 3, 1954.) 8 claims. Assigned to American Viscose Corp. [Cl. 106-165.] The coagulation modifier is a cycloimidine derivative, such as Miranol.

Miller, John D. Multi-ply carton construction. U. S. patent 2,908,436. Filed March 3, 1958. 4 claims. Assigned to Owens-Illinois Glass Co. [Cl. 229-15.] A traylike handled partitioned carton is provided for supporting four six-packs of canned or bottled goods.

Mott, John H. Box stitching machine. U. S. patent 2,908,011. Filed Nov. 21, 1956. 5 claims. [Cl. 1-106.]

Mullis, Carl W., Sr. Rotary debarker having pivotable bark-removing tools biased by fluid under pressure in an annular tank. U. S. patent 2,908,302. Filed July 15, 1957. 10 claims. [Cl. 144-208.]

Rich, John P., and Luthi, Oscar. Apparatus for screening pulp. U. S. patent 2,908,390. Filed Jan. 28, 1958. 5 claims. [Cl. 209-273.] A cylindrical pulp screen permits screening at high consistencies.

Roberts, Frank B. Box filling apparatus. U. S. patent 2,908,475. Filed March 7, 1955. 2 claims. [Cl. 249-59.] A carton is filled with a predetermined weight of fruit or the like.

Rumsey, Herbert, Jr. Packaged sausage product and method of making same. U. S. patent 2,908,576. Filed Dec. 5, 1956. 8 claims. Assigned to W. R. Grace & Co. [Cl. 99-174.] The sausages are banded with a paper strip and overwrapped in film.

Scott, Milton J. Modified melamine laminating resins. U. S. patent 2,908,603. Filed Feb. 1, 1957. 9 claims. Assigned to Monsanto Chemical Co. [Cl. 154-140.] A paper-laminating agent with improved flow properties is provided.

Stone, Claire E., and Layton, J. C. Dispenser for rolls of strip material. U. S. patent 2,908,450. Filed Nov. 28, 1956. 11 claims. Assigned to Towlsaver, Inc. [Cl. 242-55.3.] A wall-mounted dispenser for rolls of toilet tissue holds a reserve roll.

Stout, Raymond K. Method of packaging cigarettes and construction of cigarette package. U. S. patent 2,908,421. Filed July 13, 1954. 6 claims. [Cl. 221-208.] A pullout device is provided for facilitating the removal of the first cigarette from the pack.

Traudt, Stephen C., Curran, Francis J., and Beale, Benjamin. Pallet. U. S. patent 2,908,464. Filed Jan. 26, 1956. 7 claims. Assigned to Bird & Son, Inc. [Cl. 248-120.] Two interlocking paperboard blanks form a pallet suitable for lifting by fork-lift truck.

Van Valkenburgh, Edward A. Reclaiming oil composition and method of making it. U. S. patent 2,908,676. Filed Oct. 18, 1956. 2 claims. [Cl. 260-97.5.] Tall oil is used in reclaiming rubber.

Vogt, Clarence W. Packages and packaging. U. S. patent 2,908,383. Filed May 18, 1956. 6 claims. [Cl. 206-65.] Butter or the like is sealed inside a series of containers formed of film and paper which are then folded together into rectangular form.

Weiss, Adolph. Re-enforced carrying handle for tied together containers and method of produciug the same. U. S. patent 2,908,438. Filed Dec. 21, 1955. 6 claims. Assigned to American Can Co. [Cl. 229-52.] A paperboard device serves

as a handle for two flat-top milk cartons which have been banded together.

Wiedenmeyer, George W. Packaging box. U. S. patent 2,908,437. Filed Sept. 17, 1956. 2 claims. Assigned to Vanant Co., Inc. [Cl. 229-39.] A carton for a radio includes integral cushioning elements.

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Ahlborg, Nils N. G., and Cederquist, Karl N. Method in the recovery of alkali and sulfur by carbonization of melt soda solutions obtained in the manufacture of cellulose. U. S. patent 2,909,407. Filed Feb. 14, 1956. 6 claims. Assigned to Stora Kopparbergs Bergslags AB. [Cl. 23-129.]

Banigan, Thomas F. Vinylidene chloride copolymer coating compositions. U. S. patent 2,909,449. Filed Feb. 3, 1956. 20 claims. Assigned to E. I. du Pont de Nemours and Co. [Cl. 117-145.] The composition improves the heat-sealability, slip, and blocking properties of cellophane.

Blackford, Benjamin B. Adhesive-coated fabrics. U. S. patent 2,909,278. Filed Sept. 3, 1957. 19 claims. Assigned to Johnson & Johnson. [Cl. 206-59.] Improved aging in pressure-sensitive adhesive tape is provided by including particulate silica in the adhesive.

Conerty, James E. Tear strip box. U. S. patent 2,909,312. Filed Oct. 9, 1956. 3 claims. Assigned to Walworth Eng. Co. [Cl. 229-51.]

Dorn, Chester. Releasable cable stake holder for trucks. U. S. patent 2,909,379. Filed March 22, 1957. 12 claims. Assigned to Spokane Kenworth Co. [Cl. 280-145.] Log bunk stakes are released.

Eddison, William B., and Erickson, Warren E. Metering mechanism. U. S. patent 2,909,017. Filed March 15, 1954. 22 claims. Assigned to Gisholt Machine Co. [Cl. 53-71.] Means for applying labels or the like to containers is provided with means to stop the machine if the container feed is stopped.

Edwards, Albert, and Peck, Harry. Sheet-feeding apparatus. U. S. patent 2,909,369. Filed May 16, 1956. 10 claims. Assigned to Linotype and Machinery Ltd. [Cl. 271-56.] The apparatus is designed to permit easy changing of the cylinder blanket of the printing press.

Fritzinger, George H. Adhesive applicators. U. S. patent 2,909,301. Filed May 25, 1956. 23 claims. [Cl. 216-29.] A paper tape carrying adhesive is applied to a surface, then the tape is stripped away leaving the adhesive.

Glaser, Philip S. Packages for coat hangers. U. S. patent 2,909,279. Filed March 27, 1958. 2 claims. [Cl. 206-65.] An assembly of coat hangers on a rod is packed into a carton.

Goldstein, Irving S. Impregnating solutions and method of impregnation therewith. U. S. patent 2,909,450. Filed June 27, 1956. 13 claims. Assigned to Koppers Co., Inc. [Cl. 117-161.] The impregnating composition described is used to render paperboard and other materials resistant to chemicals.

Govang, James A. Shipping and dispensing cartons. U. S. patent 2,909,310. Filed Sept. 22, 1958. 7 claims. Assigned to New Haven Board & Carton Co. [Cl. 229-17.] A bird feed carton has a dispensing trough.

Hendrikson, Thor O., and Smedberg, Nels H. Logging bunks. U. S. patent 2,909,130. Filed Dec. 27, 1954. 12 claims. [Cl. 105-282.]

Kaveler, Herman H. Gypsum cements. U. S. patent 2,909,223. Filed May 5, 1952. 17 claims. Assigned to Phillips Petroleum Co. [Cl. 166-31.] Carboxymethylhydroxyethylcellulose is used.

Lawrence, Michael J. Carton setup machine. U. S. patent 2,909,105. Filed Oct. 3, 1957. 5 claims. Assigned to Chicago Carton Co. [Cl. 93-51.]

Levitt, Marvin R. Multiple cell cartons. U. S. patent 2,909,311. Filed Jan. 2, 1958. 3 claims. [Cl. 229-28.] A bottle carrier or the like is formed from a single blank and is collapsible.

Lofgren, Gustaf E. Disposable dust bags. U. S. patent 2,909,238. Filed June 10, 1958. 2 claims. Assigned to Electrolux Corp. [Cl. 183-51.] Paper filter bags for vacuum cleaners are provided.

MacBride, Herbert L. Taping machine. U. S. patent 2,909,019. Filed Jan. 26, 1956. 6 claims. Assigned to Sylvania Elec. Prods., Inc. [Cl. 53-198.] Electrical lead wires are taped together.

Maish, Jay H. Mailing pieces. U. S. patent 2,909,313. Filed Aug. 24, 1955. 3 claims. Assigned to Jay H. Maish Co. [Cl. 229-92.8.] A pocket for carrying a return card is included.

Marshall, Preston F. Grass seed mat and process for making same. U. S. patent 2,909,003. Filed Nov. 30, 1955. 9 claims. Assigned to The Kendall Co. [47-56.] The seed is incorporated in a web of textile fibers, and a creped paper backing is applied.

Nilsson, Nils G. H., and Stridsberg, Karl Å. Apparatus for grinding a material suspended in a liquid. U. S. patent Filed Dec. 8, 1955. 6 claims. [Cl. 241-46.] Wood pulp in slurry form is ground.

O'Dell, Leonard J. Filter apparatus. U. S. patent 2,909,237. Filed Dec. 23, 1957. 13 claims. Assigned to American Air Filter Co., Inc. [Cl. 183-44.] Two sheets of paper in spaced parallel relation with interconnecting tabs folded from each sheet form an air filter.

Osenberg, Werner. Manufacture of single or multistage grinding rings or the like. U. S. patent 2,909,417. Filed Dec. 12, 1955. 10 claims. Assigned to Bisterfield & Stolting. [Cl. 51-298.] Hollow abrasive cylinders include wound layers of resin-impregnated fabric and interspersed layers of abrasive.

Patten, Lorraine E., and Kelly, Harold C. Method of coating articles of food and product obtained thereby. U. S. patent 2,909,434. Filed Dec. 23, 1957. 19 claims. Assigned to The Dow Chemical Co. [Cl. 99-166.] Ethylcellulose is used.

Redfarn, Cyril A., and Coates, Harold. Process of flameproofing cellulosic and proteinaceous materials and resulting product. U. S. patent 2,909,446. Filed May 2, 1955. 11 claims. Assigned to Albright & Wilson Ltd. [Cl. 117-138.] Paper and textiles are flameproofed.

Robbins, Frederick P. Spring binder. U. S. patent 2,909,179. Filed May 10, 1957. 9 claims. [Cl. 129-24.] This is a loose-leaf binder.

Shackelford, Jesse J. Box partition assembly device. U. S. patent 2,909,104. Filed July 21, 1955. 14 claims. Assigned to Fairmont Box Co. [Cl. 93-38.]

Sherrill, Joseph H. Carton packing apparatus. U. S. patent 2,909,016. Filed Dec. 22, 1955. 11 claims. Assigned to R. J. Reynolds Tobacco Co. [Cl. 53-61.] Cigarette packs are grouped and cartoned.

Turner, Albert V. Packaging machine. U. S. patent 2,909,018. Filed Feb. 25, 1957. 12 claims. [Cl. 53-124.] Leafy produce is packed into a bag and sealed.

Wilson, Lucius H., Hopkins, William C., and Stafiej, Stanley F. Manufacture of rosin and rosin size of decreased latent foaming tendency. U. S. patent 2,909,514. Filed March 7, 1957. 8 claims. Assigned to American Cyanamid Co. [Cl. 260-97.]

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Barr, Charles L. Packaging machine. U. S. patent 2,909,874. Filed Aug. 27, 1957. 18 claims. Assigned to F. B. Redington Co. [Cl. 53-75.] Cartons are erected, filled, closed, and discharged.

Beachler, Edward D. Felt run arrangement. U. S. patent 2,909,848. Filed March 16, 1956. 3 claims. Assigned to Beloit Iron Works. [Cl. 34-117.] The felts are arranged in a drier section to prevent developing air currents which tend to break the web.

Bennett, Herbert L., and Hill, Howard. Base-type holder for paper containers. U. S. patent 2,910,219. Filed Sept. 3, 1957. 12 claims. Assigned to American Can Co. [Cl. 229-1.5.] A molded plastic holder is designed to be pressed into supporting engagement with the recessed bottom of a paper cup.

Bermingham, Arthur T., Jr., and Procido, Richard M. Return envelope construction. U. S. patent 2,910,222. Filed March 18, 1957. 1 claim. Assigned to Columbia Envelope Co. [Cl. 229-73.]

Berry, William, Rose, Richard A., Phillips, Cyril H., and Oswin, Charles R. Production of moistureproof sheet wrapping material coated with copolymers applied from aqueous dispersions. U. S. patent 2,910,385. Filed Oct. 31, 1955. 6 claims. Assigned to British Cellophane Ltd. [Cl. 117-138.8.]

Brown, George W., Cartwright, Conrad Y., Hutter, George L., McCann, Farrell A., Nyberg, John C., Skeirik, Roy M., and Krag, Niels. Collating apparatus. U. S. patent 2,909,968. Filed July 30, 1956. 8 claims. Assigned to Telemeter Magnetics, Inc. [Cl. 93-1.] Tabs are cut from paper tape, punch coded, and attached to documents.

Coles, Derek H. Printing plates for use in offset printing. U. S. patent 2,910,358. Filed Feb. 11, 1953. 5 claims. [Cl. 96-33.]

Cook, George R., and Cortiss, Warren W. Adhesive lubricants. U. S. patent 2,910,440. Filed July 23, 1957. 11 claims. Assigned to The Pure Oil Co. [Cl. 252-57.] Methyl esters of rosin are used.

Cox, Norman L., and Nicol, William D. Spinning viscose. U. S. patent 2,910,341. Filed Feb. 17, 1954. 24 claims. Assigned to E. I. du Pont de Nemours and Co. [Cl. 18-54.] The coagulation modifier is a diamine such as trimethylenediamine.

Cummings, Thomas N., Peterson, Benjamin R., Jr., and Shiu, Thomas B. Containers wrapping assemblage. U. S. patent 2,909,877. Filed March 8, 1955. 6 claims. Assigned to CPS Mfg. Co. [Cl. 53-180.] Cylindrical containers loaded with ice cream and provided with handle sticks are wrapped in paper.

Durant, Leonard G., Irvine, James E., Pennington, Rohe V., and Surino, Alphonse. Asphalt dispersion in waste cellulosic material. U. S. patent 2,910,398. Filed Oct. 19, 1956. 8 claims. Assigned to E. D. Jones Corp. [Cl. 162-4.] Waste

paper containing asphalt is prepared for use in making paper by dispersing the asphalt in the fibers of the defibered paper.

Emmert, George W., and Barr, Leslie. Tape dispensing device. U. S. patent 2,910,218. Filed Sept. 22, 1955. 6 claims. Assigned to Federal Tool Corp. [Cl. 225-26.] Pressure-sensitive tape is drawn from the device in a direction parallel to the axis of the tape supply roll.

Emmert, George W., and Safianoff, Albert. Tape dispenser. U. S. patent 2,910,217. Filed Sept. 22, 1955. 6 claims. Assigned to Federal Tool Corp. [Cl. 225-25.] This is similar to U. S. patent 2,910,218 (Oct. 27, 1959).

Foreman, Calvin E. Measuring dispenser for granular substances. U. S. patent 2,910,213. Filed July 23, 1958. 3 claims. [Cl. 222-456.] A paperboard dispensing container for soap chips or the like is provided with an integral interior measuring element.

Gibbons, Earl E. Bag holder. U. S. patent 2,910,257. Filed May 8, 1956. 2 claims. [Cl. 248-101.] Means are provided for holding a bag in open position while it is being filled.

Gouner, Aubrey L. Device for advertising and displaying neckties. U. S. patent 2,910,214. Filed June 3, 1958. 1 claim. Assigned to Wembley, Inc. [Cl. 223-87.] A paperboard blank folds into a device for supporting a necktie for merchandising display.

Hamilton, Joseph P. Produce tray or container. U. S. patent 2,910,220. Filed May 3, 1957. 3 claims. Assigned to Longview Fibre Co. [Cl. 229-15.] An open-top tray formed from a single blank has a partition and wire elements for use in stacking the trays.

Hornbostel, Lloyd. Drum drier mechanism. U. S. patent 2,909,849. Filed Nov. 25, 1955. 4 claims. Assigned to Beloit Iron Works. [Cl. 34-124.] Steam is passed through pipes near the shell and heat is transferred to the shell by a liquid maintained around the inner periphery of the shell by centrifugal force.

Hornbostel, Lloyd, and Justus, Edgar J. Dryer section arrangement for paper machines. U. S. patent 2,909,847. Filed Oct. 17, 1955. 5 claims. Assigned to Beloit Iron Works. [Cl. 34-111.] A system of hoods, vents, baffles, etc., improve air flow to prevent overdrying the web edges.

Imbs, Joseph F. Folding and sealing machines. U. S. patent 2,909,875. Filed May 14, 1953. 8 claims. [Cl. 53-76.] The mouth of a filled bag is folded and sealed.

Jordan, Arthur D., Jr. Process for making cellulose fibrous sheet. U. S. patent 2,910,399. Filed April 9, 1956. 7 claims. Assigned to Rohm & Haas Co. [Cl. 162-166. A method for depositing a polymer onto the fibers of the furnish is provided.

Kelchner, Harley E. Sheet feeding apparatus. U. S. patent 2,910,293. Filed Aug. 29, 1957. 25 claims. Assigned to Burroughs Corp. [Cl. 271-52.] A sheet-feeding mechanism is provided with means to register the sheets.

Kerr, Charles E. Carton filling apparatus. U. S. patent 2,910,212. Filed Jan. 13, 1954. (Divided; original Dec. 31, 1948.) 6 claims. Assigned to Food Machinery and Chemical Corp. [Cl. 222-168.5.] Cartons of the end-opening type are fed, filled, and sealed.

Lawrence, Joseph L., and Allen, Philip H. Fanfolding machine. U. S. patent 2,910,292. Filed July 23, 1954. 5 claims. Assigned to Cycle Equipment Co. [Cl. 270-73.] The machine fanfolds paper tape for teletype systems without interference from static electricity picked up by the tape.

Loechl, Clarence J. Drying gypsum wall board. U. S. patent 2.909,850. Filed Feb. 23, 1956. 5 claims. Assigned to The Celotex Corp. [Cl. 34-205.] The edges of the board are protected from excessive drying.

McGihon, Leonard. Casing machine for cartons. U. S. patent 2,909,876. Filed Nov. 16, 1955. 3 claims. Assigned to King Sales & Eng. Co. [Cl. 53-159.] Six-pack cartons are cased.

Means, Perry G. Continuous hot pressing machine for the manufacture of compressed boards. U. S. patent 2,909,804. Filed Sept. 16, 1959. 7 claims. [Cl. 18-4.]

Mumma, Harold J. Carton closing machine. U. S. patent 2,909,880. Filed July 26, 1955. 20 claims. Assigned to Food Machinery and Chemical Corp. [Cl. 53-377.] The machine closes the hinged covers of molded pulp egg cartons after the cartons have been filled.

Owen, Richard. Heat-sensitive copying-paper. U. S. patent 2,910,377. Filed June 28, 1956. 11 claims. Assigned to Minnesota Mining & Mfg. Co. [Cl. 117-36.]

Randall, Boardman M., and Frobisher, Ralph S. Structural reticulated webs or honeycombs and curtain wall panels made from same. U. S. patent 2,910,396. Filed Nov. 12, 1952. 9 claims. Assigned to The Bettinger Corp. [Cl. 154-45.9.] Paper honeycomb is coated on all surfaces with a cementitious material.

Rasch, Joachim. Corrosion resistance apparatus for use with acid chlorite solutions. U. S. patent 2,910,342. Filed Sept. 6, 1956. 3 claims. Assigned to Deutsche Gold- und Silber-Scheideanstalt vormals Roessler. [Cl. 21-2.5.] Cellulose-bleaching equipment has a surface layer of anodically oxidized aluminum.

Sheetz, Charles E. Bag holding apparatus. U. S. patent 2,910,258. Filed Sept. 16, 1957. 9 claims. Assigned to Food Machinery and Chemical Corp. [Cl. 248-101.] A bag is held with mouth open adjacent the filling chute of a bag-filling machine.

Shiner, Edward A. Method of making seamless viscose-regenerated cellulose tubing. U. S. patent 2,910,380. Filed Oct. 13, 1955. 7 claims. Assigned to Union Carbide Corp. [Cl. 117-66.] Viscose is applied to manila hemp paper, and then regenerated.

Shiu, Thomas B. Continuous-flow confectionery packaging machine. U. S. patent 2,909,878. Filed Dec. 13, 1957. 25 claims. Assigned 25% to Nicholas A. Cummings, 25% to Thomas N. Cummings, and 25% to Benjamin R. Peterson, Jr. [Cl. 53-183.]

Stankey, James A., and Slater, Morris N. Method of aluminizing phosphor screens. U. S. patent 2,910,376. Filed March 27, 1957. 11 claims. Assigned to Radio Corp. of America. [Cl. 117-33.5.] Cellulose nitrate is used.

Styers, Henry H. Bag forming and sealing machine. U. S. patent 2,909,969. Filed June 12, 1958. 18 claims. Assigned to Poly-Cut Corp. [Cl. 93-8.]

Watt, William R. Process for producing cellulose thiourethanes. U. S. patent 2,910,466. Filed Feb. 6, 1956. 13 claims. Assigned to American Viscose Corp. [Cl. 260-216.]

Whiton, Arthur L. Crate. U. S. patent 2,910,221. Filed Aug. 1, 1958. 8 claims. Assigned to Chicago Mill and Lumber Co. [Cl. 229-23.] A collapsible shipping crate is formed of wood-cleat-reinforced paperboard.

Williams, Barney B. Cigarette package. U. S. patent 2,910,175. Filed April 24, 1956. 2 claims. [Cl. 206-41.] The pack has corner-opening means and reinforcing panels preventing collapse as the cigarettes are used.

Wimmer, Ernest L. Starch cross-linked with hexahydro-1,3,-5-triacryloyl-s-triazine. U. S. patent 2,910,467. Filed Jan. 18, 1956. 5 claims. Assigned to Chas. A. Krause Milling Co. [Cl. 260-233.3.] The product is of use in converting adhesives.

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Armento, William H., and Hebauf, Nikolaus. Coloration of synthetic polymeric material. U. S. patent 2,911,314. Filed Dec. 17, 1954. 9 claims. Assigned to General Aniline & Film Corp. [Cl. 106-168.] Various cellulosic materials are colored with a light-fast brown shade.

Bartlett, Richard J., Hall, Claude C., and Martell, Jack A. Box closing machine. U. S. patent 2,910,815. Filed Aug. 14, 1953. 6 claims. Assigned to Smith, Kline & French Labs. [Cl. 53-374.]

Beachler, Edward D. Stock distributor assembly. U. S. patent 2,911,041. Filed Dec. 27, 1956. 5 claims. Assigned to Beloit Iron Works. [Cl. 162-336.]

Burton, Stuart W. Hosiery package. U. S. patent 2,911,-093. Filed Oct. 2, 1958. 1 claim. Assigned to Thornton Knitting Co., Inc. [Cl. 206-45.33.] Several pairs of men's hose are supported on a paperboard member and the assembly packed in a transparent bag.

Chodorowski, Wieslaw T. Web severing devices in web feeding machines. U. S. patent 2,911,132. Filed Nov. 5, 1957. 3 claims. Assigned to Strachan & Henshaw Ltd. [Cl. 225-101.] The apparatus is primarily for use in a bag-making machine.

Dienner, John A. Self-opening package. U. S. patent 2,911,129. Filed Dec. 23, 1957. 7 claims. [Cl. 222-83.] A device is positioned within a carton so that a blow on the outside of the carton drives the device through the carton wall to form a dispensing opening.

Doughty, Joseph B. Method of making a modified sulfate lignin reinforced butadiene-acrylonitrile rubber. U. S. patent 2,911,383. Filed June 27, 1955. 3 claims. Assigned to West Virginia Pulp and Paper Co. [Cl. 260-17.5.]

Drake, George L., Jr., Reeves, Wilson A., and Chance, Leon H. Flame resistant organic textiles and method of production. U. S. patent 2,911,325. Filed April 24, 1957. (Divided; original filed June 5, 1956.) 8 claims. Assigned to U. S. Secretary of Agr. [Cl. 117-136.] Paper and textiles are treated.

Erie, Edward. Tissue dispenser. U. S. patent 2,911,175. Filed June 9, 1955. 1 claim. [Cl. 248-216.] A holder attaches to the upholstery of an auto and supports a box of tissues in dispensing position.

Evans, John G., Landells, George, and Meals, William S. Treatment of materials to improve water-repellancy. U. S. patent 2,911,324. Filed Jan. 3, 1956. 1 claim. Assigned to Bradford Dyers' Assoc. Ltd. [Cl. 117-135.5.] Paper and textiles are rendered waterproof.

Fookes, James H., and Nutter, Richard A. Ethyl cellulose compositions. U. S. patent 2,911,315. Filed Jan. 23, 1958. 6 claims. Assigned to Dow Chem. Co. [Cl. 106-189.] Ethylcellulose is plasticized so as to be heat-sealable and useful in packaging.

Griem, Milton E. Sliced food package. U. S. patent 2,911,306. Filed Sept. 3, 1957. 5 claims. Assigned to Milprint, Inc. [Cl. 99-171.] A shingled assembly of bacon slices is placed on a paperboard backing and overwrapped in plastic film.

Haney, Marcus D., Jr., and Ambruster, Larner. Treatment of cellulosic fiber and composition therefor. U. S. patent 2,911,326. Filed Nov. 8, 1956. 3 claims. Assigned to E. I. du Pont de Nemours and Co. [Cl. 117-139.4.] Crease-resistant effects are produced in cellulosic fabrics.

Hochmuth, Frank W. Method of burning waste liquors. U. S. patent 2,911,284. Filed June 1, 1955. 5 claims. Assigned to Combustion Eng., Inc. [Cl. 23-48.]

Hornbostel, Lloyd. Press section. U. S. patent 2,911,040. Filed Jan. 29, 1958. 7 claims. Assigned to Beloit Iron Works. [Cl. 162-305.]

Hornbostel, Lloyd, and Justus, Edgar J. Fourdrinier wire testing apparatus. U. S. patent 2,910,863. Filed March 8, 1957. 6 claims. Assigned to Beloit Iron Works. [Cl. 73-86.]

Hornbostel, Lloyd, and Justus, Edgar J. Paper machine forming section. U. S. patent 2,911,039. Filed Jan. 18, 1957. 5 claims. Assigned to Beloit Iron Works. [Cl. 162-303.] A twin-wire fourdrinier is described.

Hotton, George R. Bottle and can carrier. U. S. patent 2,911,126. Filed Nov. 19, 1954. 1 claim. [Cl. 220-115.]

Justus, Edgar J. Suction roll silencer. U. S. patent 2,911,042. Filed Jan. 24, 1956. 8 claims. Assigned to Beloit Iron Works. [Cl. 162-371.]

Klein, Elias, and Weaver, Jeremiah W. Field treatment for making cellulosic fabrics flameproof and resistant to certain chemical warfare gases. U. S. patent 2,911,322. Filed Oct. 29, 1957. 5 claims. Assigned to U. S. Secretary of the Army. [Cl. 117-76.]

Lerch, Brooke W. Shock-resistant, adhesive tapes. U. S. patent 2,911,318. Filed April 4, 1956. 4 claims. Assigned to Western Elec. Co., Inc. [Cl. 117-33.]

McCormick, Frank. Display stand. U. S. patent 2,911,106. Filed March 19, 1957. 5 claims. Assigned to Federal Carton Corp. [Cl. 211-69.] A collapsible easel-type stand is formed from paperboard for displaying ballpoint pens and the like.

Mercer, John C. Milk cartons, etc. U. S. patent 2,911,135. Filed July 29, 1957. 3 claims. Assigned 10% to Archworth Martin. [Cl. 229-17.] A flat-top dispensing carton for milk or other beverages is formed from a one-piece paperboard blank.

Metcalfe, William K. Drying equalizer arrangement. U. S. patent 2,910,784. Filed Oct. 10,1957. 3 claims. Assigned to Midland-Ross Corp. [Cl. 34-114.] A paper machine drier section is provided with means for establishing desirable airflow characteristics around the web and drying cylinders.

Micciche, Frank. Container. U. S. patent 2,911,092. Filed Feb. 23, 1956. 1 claim. [Cl. 206-41.] A flat box holds 20 cigarettes in a single row.

Phillips, C. H. Production of moistureproof sheet wrapping materials. U. S. patent 2,911,320. Filed April 19, 1957. 6 claims. Assigned to British Cellophane, Ltd. [Cl. 117-64.] A polyvinylidene chloride copolymer layer is applied from aqueous solution to the surface of paper or cellophane without streaking at high coating speeds.

Richardson, Frank A. Apparatus for the counting of sheets of material, for example, bank notes. U. S. patent 2,911,216. Filed Sept. 21, 1956. 1 claim. Assigned to De La Rue Co. Ltd. [Cl. 271-27.]

Rumsey, Herbert, Jr. Commercial package and method of making the same. U. S. patent 2,911,305. Filed July 26, 1957. (Divided; original July 20, 1953.) 9 claims. Assigned to W. R. Grace & Co. [Cl. 99-171.] Two strips of paper laminated about a wire strand are used to close a sausagelike package of a meat product.

Rzemienski, Walter S. Paper packet processing machine. U. S. patent 2,911,131. Filed Dec. 29, 1954. 8 claims. Assigned to General Motors Corp. [Cl. 225-100.] Carbons are removed from manifold packs and the other sheets formed into separate stacks.

Seidman, Louis. Display carton and attachment therefor. U. S. patent 2,911,124. Filed Aug. 22, 1956. 2 claims. Assigned to Glaser Bros. [Cl. 217-61.] A small display carton is supported in association with a standard cigar box.

Stone, Orison W. Reinforced handle construction for paperboard cartons. U. S. patent 2,911,136. Filed Feb. 20, 1958. 4 claims. Assigned to Continental Can Co., Inc. [Cl. 229-52.] The carton is a six-pack can carrier.

Stuck, Harold D. Apparatus and method for disintegrating fibrous material. U. S. patent 2,911,334. Filed Nov. 18, 1955. 14 claims. Assigned to John W. Bolton & Sons, Inc. [Cl. 162-17.] Bagasse, bamboo, and other fibrous materials are defibered.

Thompson, William E., and Leeder, George S. Oxygenated crystalline polypropylene, method of making, and wax composition containing same. U. S. patent 2.911,384. Filed Feb. 5, 1957. 6 claims. Assigned to Sun Oil Co. [Cl. 260-28.5] The composition is of use in coating milk cartons.

Wenger, Abraham. Method of printing designs on confections. U. S. patent 2,911,304. Filed July 11, 1955. 5 claims. Assigned to Candy Crafts, Inc. [Cl. 99-137.] Methylcellulose is used.

Wennberg, Olov C. G. Log-peeling machine having scraper tools provided with bark-deflecting wings. U. S. patent 2,911,020. Filed Jan. 22, 1953. 5 claims. [Cl. 144-208.]

Zuercher, Anthony J., and Schweizer, Paul. Error control mechanism for stuffing machine. U. S. patent 2,911,213. Filed Jan. 16, 1958. 6 claims. Assigned to T. W. & C. B. Sheridan Co. [Cl. 270-57.] The machine collates newspaper sections.

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Baker, Robert M. Log debarking apparatus. U. S. patent 2,912,023. Filed Sept. 19, 1957. 17 claims. Assigned 50% to Norval K. Morey. [Cl. 144-208.]

Bidwell, Howard. Method and apparatus for the treatment of paper stocks. U. S. patent 2,912,174. Filed Sept. 30, 1950. 21 claims. Assigned 50% to Rachel Bidwell. [Cl. 241-15.] The machine fiberizes paper stock.

Biel, Hans, and Pfäfflle, Ernst. Method for the manufacture of ring book sheets in a combined operation. U. S. patent 2,911,888. Filed Dec. 13, 1955. 1 claim. Assigned to Hans A. Stickinger. [Cl. 93-1.]

Bishop, Edwin V. Packaging means for articles that are deleteriously affected by moisture. U. S. patent 2,912,138. Filed May 19, 1958. 2 claims. Assigned to Kirwan Y. Messick. [Cl. 220-85.] A paperboard tube for packing blueprints is impervious to moisture, with means being provided to maintain the pressure in the tube equal to atmospheric pressure.

Boggs, Herbert D. Core compactor. U. S. patent 2,912,041. Filed Jan. 28, 1954. 15 claims. Assigned to H. D. Boggs Co., Ltd. [Cl. 154-1.] An air-laying method and means are provided for depositing a mixture of fiber resin into the sand form of a tube.

Bramhill, Percy W. Imperforate wrappings for cigarettes. U. S. patent 2,911,979. Filed Feb. 18, 1957. 1 claim. [Cl. 131-4.] End caps are applied to cigarettes so the pack needs no moistureproof wrapper.

Burke, George F. C. String tag attaching devices. U. S. patent 2,911,928. Filed Feb. 21, 1958. 9 claims. Assigned to United Shoe Machinery Corp. [Cl. 112-104.] The machine secures a paper tag to a garment with string.

Cole, Gerald E. Label dispenser. U. S. patent 2,912,140. Filed March 7, 1957. 5 claims. Assigned to Kleen-Stik Prods., Inc. [Cl. 221-70.] The device dispenses labels from a supply roll of tape carrying the pressure-sensitive labels.

Cross, Cedric B., and Melhorn, Carl E. Article feeding means. U. S. patent 2,912,092. Filed Aug. 19, 1957. 11 claims. Assigned to Package Machinery Co. [Cl. 198-23.] A wrapping machine is provided with means for feeding the articles to be wrapped at high speed in spaced apart single-file relation.

Doran, Donald P. Folding paperboard carton. U. S. patent 2,912, 154. Filed Feb. 6, 1956. 6 claims. Assigned to Continental Can Co., Inc. [Cl. 229-34.] A collapsible hollow-walled carton is described.

Drisch, Nicolas, and Meyer, Pierre. Process of spinning viscose containing thiodiglycol. U. S. patent 2,912,299. Filed Sept. 6, 1955. 2 claims. Assigned to Chimotex Societe Anonyme. [Cl. 18-54.]

Fink, Raymond E. Packages of cylindrical articles. U. S. patent 2,912,104. Filed Sept. 22, 1958. 4 claims. Assigned to New Haven Board and Carton Co. [Cl. 206-65.] A wrap-around paperboard carrier for holding a single row of cans is provided.

Frank, Anton R., and Giles, William H. Wrapping mechanism and a method of wrapping articles. U. S. patent 2.911,774. Filed July 20, 1956. 2 claims. Assigned to Van Buren Machine Corp. [Cl. 53-27.] A box blank is deposited on a wrapper sheet and the two are folded together about a bar of soap or the like.

Frankle, Harry R., and Crane, Perry T. Paper feed. U. S. patent 2,912,240. Filed March 31, 1955. 11 claims. [Cl. 271-20.] This is a sheet-feeder for a duplicating or printing machine.

French, Hector E. Loose-leaf binders. U. S. patent 2,911,977. Filed Aug. 29, 1957. 5 claims. [Cl. 129-41.]

Geary, Robert J. Insect combatting device. U. S. patent

2,911,756. Filed Dec. 8, 1955. 2 claims. [Cl. 43-114.] A form of flypaper is provided.

Gross, Frank C. Adhesive applying device. U. S. patent 2,911,942. Filed Feb. 25, 1957. 24 claims. Assigned to Package Machinery Co. [Cl. 118-202.] Adhesive is applied to cartons or blanks without fouling the machinery.

Guichard, Raymond A. E. Label holder for document filing systems. U. S. patent 2,911,976. Filed Sept. 6, 1956. 2 claims. [Cl. 129-16.8.]

Gulick, Kenneth H. Pile elevating mechanism and control therefore. U. S. patent 2,912,243. Filed Dec. 16, 1955. 20 claims. Assigned to Harris-Intertype Corp. [Cl. 271-62.] This is a sheet-feeder.

Hennessey, Russell J., and Dunning, Robert M. Can carriers. U. S. patent 2,912,103. Filed Aug. 26, 1957. 8 claims. Assigned to Waldorf Paper Prods. Co. [Cl. 206-65.] A traylike carton is provided for supporting two cans in coaxial relation.

Henny, Willi. Container closure and pouring attachment. U. S. patent 2,912,146. Filed May 20, 1957. 1 claim. [Cl. 222-531.] A metal device is attached to a paperboard container to form a pouring spout with hinged cover.

Japel, Joseph P. Method of making components for printed circuits. U. S. patent 2,912,312. Filed Oct. 10, 1956. 3 claims. Assigned to Cleveland Metal Specialties Co. [Cl. 41-43.]

Karnahl, Friedrich H. Sheet folding machine with several folding devices. U. S. patent 2,912,238. Filed July 9, 1956. 10 claims. Assigned to Carl Kruse. [Cl. 270-81.]

La Bombard, Leon E. Apparatus and method for feeding sheets. U. S. patent 2,912,239. Filed Nov. 25, 1957. 32 claims. [Cl. 271-6.] An apparatus is provided for feeding large box blanks from the bottom of a supply stack.

Lange, Ferdinand L. Folding container. U. S. patent 2,912,153. Filed Feb. 8, 1957. 6 claims. [Cl. 229-16.] A hinged lid folding box is designed to be steam and aroma tight.

Lavanchy, Patricia B. Product and method of manufacture. U. S. patent 2,912, 348. Filed April 13, 1956. 12 claims. Assigned to Johnson & Johnson. [Cl. 117-76.] Improved adhesion of backing to adhesive is provided in a pressure-sensitive tape.

Lawnhurst, Richard. Garment hanger and display structure. U. S. patent 2,912,148. Filed Oct. 24, 1956. 4 claims. [Cl. 223-87.] The hanger is of paperboard and supports garments in three-dimensional fashion.

Luczek, Walter, and Cross, Cedric B. Tucking mechanism for wrapping machines. U. S. patent 2,911,779. Filed Jan. 17, 1957. 3 claims. Assigned to Package Machinery Co. [Cl. 53-378.]

McEwen, Robert L., Raleigh, Charles W., and Price, Carl E. Method of brightening high density cellulose pulps with a reducing bleaching salt at high speeds. U. S. patent 2,912,297. Filed Dec. 2, 1954. 2 claims. Assigned to Food Machinery and Chem. Corp. [Cl. 162-82.]

Miller, William L. Bottom seam squeezer for paper cups. U. S. patent 2,911,890. Filed Jan. 2, 1957. 11 claims. Assigned to Continental Can Co., Inc. [Cl. 93-55.1.]

Miramontes, Luis. Procedure for obtaining sapogenins from natural undried products. U. S. patent 2,912,362. Filed March 6, 1957. 2 claims. Assigned to G. D. Searle & Co. [Cl. 195-32.] The sapogenins are obtained from Dioscorea roots.

Newman, Douglas A., and Dixon, Harold F. E. Pressure-sensitive transfer element for placing smudge-resistant marks. U. S. patent 2,912,344. Filed Oct. 11, 1957. 7 claims. Assigned to Columbia Ribbon & Carbon Mfg. Co., Inc. [Cl. 117-36.] This is a carbon paper.

Ozor, Louis. Bag intucking device. U. S. patent 2,911,778. Filed Jan. 27, 1956. 5 claims. [Cl. 53-371.]

Pepitone, Vincent, and Luczek, Walter. Mechanism for encircling an article in a wrapper. U. S. patent 2,911,777. Filed Sept. 18, 1957. 1 claim. Assigned to Package Machinery Co. [Cl. 53-228.]

Phillips, Wallace G., Hall, William O., and Overstreet, Henry H. Machine for applying handles to paper bags or the like. U. S. patent 2,911,927. Filed Feb. 11, 1957. 5 claims. [Cl. 112-2.]

Richardson, Frank A. Apparatus for counting sheets of paper. U. S. patent 2,912,242. Filed Sept. 23, 1957. 6 claims. Assigned to De La Rue Co., Ltd. [Cl. 271-27.]

Schult, Hans W. Blow off conveyor device for paper cups or the like. U. S. patent 2,912,282. Filed May 16, 1957. 3 claims. Assigned to Solo Cup Co. [Cl. 302-2.]

Scott, Arthur L. Package for fishing line. U. S. patent 2,912,102. Filed July 29, 1958. 5 claims. Assigned to Soo Valley Co. [Cl. 206-56.]

Taylor, William H. Automatic reversing mechanism for magazines and the like. U. S. patent 2,911,891. Filed July 2, 1956. 6 claims. [Cl. 93-93.] Stitched magazines being received for stacking are alternately reversed so they may be stacked evenly.

Tonkin, Kenneth J. Corner separator mechanism for duplicators. U. S. patent 2,912,241. Filed Dec. 13, 1957. 8 claims. Assigned to A. B. Dick Co. [Cl. 271-22.] This is a sheet-feeder.

Trussell, Clarence D. Hand sanders. U. S. patent 2,911,769. Filed June 3, 1958. 1 claim. [Cl. 51-186.] The device comprises a rectangular tube of sandpaper taped onto a supporting block.

Welsh, Ormonde P. Box folding machine. U. S. patent 2,911,889. Filed June 25, 1954. 24 claims. [Cl. 93-49.]

White, Roger L. Moisture retaining container. U. S. patent 2,912,152. Filed Dec. 9, 1957. 4 claims. Assigned to Lawrence Paper Co. [Cl. 229-14.] A meat carton is formed of multi-ply corrugated with one ply of asphalt-impregnated liquid-proof material.

Widzer, Arthur S. Bag-filling machine. U. S. patent 2,912,283. Filed Aug. 20, 1956. 5 claims. Assigned to B. F. Goodrich Co. [Cl. 302-29.]

Yezek, Milton, and Utschig, Walter C. Process of producing glossy wax-coated paper. U. S. patent 2,912,347. Filed June 3, 1957. 8 claims. Assigned to General Foods Corp. [Cl. 117-64.]

Young, Elmer. Identifying device for documents. U. S. patent 2,912,259. Filed Feb. 21, 1958. 2 claims. [Cl. 283-8.] A folded paper device attaches to a check for recording the fingerprint of a person passing the check.

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Arnold, James W. Display support. U. S. patent 2,913,209. Filed Dec. 2, 1954. 3 claims. Assigned to Kimberly-Clark Corp. [Cl. 248-201.] A rod for mounting a display sign on a carton is formed of telescoping paper tubes.

Black, Robert S., and Carroll, James S. Roll type glue spreaders, surface coaters, and the like. U. S. patent 2,912,960. Filed Aug. 29, 1956. 25 claims. [Cl. 118-5.]

Bowman, Paul F. Carton sealing machine. U. S. patent 2,912,806. Filed Dec. 4, 1958. 15 claims. Assigned to Alford Package Machines, Inc. [Cl. 53-76.]

Bowman, Paul F. Machine for applying end closures to cartons. U. S. patent 2,912,809. Filed Feb. 6, 1958. 12 claims. Assigned to Continental Paper Co. [Cl. 53-137.]

Brunsing, Rex L. Holder for cans and multican package. U. S. patent 2,913,105. Filed Dec. 31, 1956. 1 claim. [Cl. 206-65.] A paperboard blank forms a holder for unitizing three cans.

Colgate, William H., Jr. Pilfer-proof merchandise display cards. U. S. patent 2.913,106. Filed Sept. 18, 1956. 8 claims. Assigned to The Gillette Co. [Cl. 206-79.]

Collins, Winifred C. Adhesive tape with low adhesion backsize coating. U. S. patent 2,913,355. Filed Dec. 27, 1955. 15 claims. Assigned to Johnson & Johnson. [Cl. 117-68.5.]

Crane, Walton B., and Slate, Edward R. Box gluing machine. U. S. patent 2,912,908. Filed July 18, 1957. 6 claims. Assigned to Allied Container Corp. [Cl. 93-52.]

Cusi, Dante S. Method of producing cellulosic pulp. U. S. patent 2,913,362. Filed June 14, 1954. 4 claims. Assigned to International Pulp Prods., Inc. [Cl. 162-55.] A method of pulping bagasse is described.

Daily, John B. Display cartons. U. S. patent 2,913,101. Filed Aug. 1, 1957. 8 claims. Assigned to Waldorf Paper Prods. Co. [Cl. 206-45.19.] A windowed display carton is provided for supporting two bottles having different dimensions.

Dazzi, Joachim. Chloro-ethers. U. S. patent 2,913,499. Filed Nov. 30, 1955. 3 claims. Assigned to Monsanto Chemical Co. [Cl. 260-613.] Paper is impregnated with the chloro-ethers described to provide a dielectric material.

Fahrenbach, Wolfgang B. Banding machine. U. S. patent 2,912,808. Filed Oct. 14, 1954. 1 claim. Assigned to Edlo, Inc. [Cl. 53-134.] A paper band is applied about two flat-top milk cartons and a handle element is applied.

Fitzgerald, John W. Snap fastener construction for envelopes. U. S. patent 2,913,164. Filed May 3, 1957. 5 claims. Assigned to Ames Safety Envelope Co. [Cl. 229-78.]

Goltz, Joseph. Box construction with stacking tab. U. S. pat. 2,913,162. Filed Nov. 2, 1956. 5 claims. [Cl. 229-27.] Partitioned boxes have integral tabs which interlock the boxes when they are stacked.

Gray, Robert B. Method of making printed circuit panels. U. S. patent 2,912,748. Filed May 28, 1956. 2 claims. Assigned to Erie Resistor Corp. [Cl. 29-155.5.] This is similar to U. S. patent 2,912,747 (Nov. 17, 1959).

Hargrove, Stone L. Disposable self feeder for rodents. U. S. patent 2,912,788. Filed Feb. 21, 1958. 1 claim. [Cl. 43-131.] A carton is used as both rat-bait container and feeder.

Harshberger, Norman P. Method of forming reinforced pulp sheets. U. S. patent 2,913,363. Filed Nov. 3, 1955. (Divided; original Oct. 3, 1950.) 2 claims. [Cl. 162-105.] Pulp sheets are formed about wire-reinforcing strands.

Jacke, Raymond E. Protective cigarette package. U. S.

patent 2,913,165. Filed Dec. 21, 1956. 8 claims. Assigned to Reynolds Metals Co. [Cl. 229-87.] The pack includes a cover cap and opener section which fits over the upper end of the pack beneath the outer wrapper.

Kummer, Ernst W. Sheet folding and envelope filling machine. U. S. patent 2,912,807. Filed Dec. 27, 1954. 34 claims. [Cl. 53-117.]

Maynard, Ralph D., Jr. Method and apparatus for packaging merchandise. U. S. patent 2,912,805. Filed March 29, 1955. 8 claims. Assigned to Washington Steel Prods., Inc. [Cl. 53-37.] Hardware items are skin-packed to a paperboard backing card.

Miller, Aaron, and Magnuson, Adolph L. Method of making paper and papermaking composition. U. S. patent 2,913,-364. Filed Nov. 18, 1954. 6 claims. Assigned to Kelco Co. [Cl. 162-178.] A galactomannan gum, an alginate, and alum are added to the furnish, depositing an alginate gel on the fibers.

Osborne, Fay H., and Kilty, Michael F., Jr. Fibrous webs and method and apparatus for making same. U. S. patent 2,913,-365. Filed Dec. 1, 1954. 23 claims. Assigned to C. H. Dexter & Sons, Inc. [Cl. 162-201.] Textile fibers are deposited within a web of paper fibers while the web is still on the forming wire.

Oshry, Howard I., Steigerwalt, Oliver I., and Heibel, Jerome D. Method of making printed circuit panels. U. S. patent 2,-912,746. Filed Oct. 10, 1955. 1 claim. Assigned to Erie Resistor Corp. [Cl. 29-155.5.] This is similar to U. S. patent 2,912,745 (Nov. 17, 1959).

Oshry, Howard I., Steigerwalt, Oliver I., and Heibel, Jerome D. Method of making printed circuit panels. U. S. patent 2,912,747. Filed Nov. 7, 1955. 1 claim. Assigned to Erie Resistor Corp. [Cl. 29-155.5.] This is similar to U. S. patent 2,912,746 (Nov. 17, 1959).

Overly, Elmer G. Envelopes. U. S. patent 2,913,163. Filed Sept. 23, 1957. 3 claims. [Cl. 229-72.] A multicompartment windowed mailing envelope is provided for holding an auto license and registration card.

Paris, Charles E. Lifting skid pallet. U. S. patent 2,913,-206. Filed July 3, 1956. 8 claims. Assigned to Mead Board Sales, Inc. [Cl. 248-120.] A paperboard pallet is provided for fork-lift truck handling of bags and cartons.

Parker, Konrad. Packaging of insulating blankets. U. S. patent 2,913,104. Filed Oct. 14, 1957. 4 claims. Assigned to The Celotex Corp. [Cl. 206-60.] An improved paper wrapper for an insulating blanket of mineral wool is provided.

Pfeiffer, Max. Card feeding devices for record card machines. U. S. patent 2,913,242. Filed Feb. 7, 1956. 5 claims. Assigned to Michael Maul. [Cl. 271-54.]

Roberts, James R. Method of and means for felting with variable suction. U. S. patent 2,912,723. Filed Jan. 30, 1953. 18 claims. Assigned to Weyerhaeuser Timber Co. [Cl. 19-156.]

Sandborn, Lloyd T., and Nall, Dan M. Chemical recovery process. U. S. patent 2,913,309. Filed May 14, 1958. 39 claims. Assigned to Crossett Chemical Co. [Cl. 23-129.] A process is provided for recovering chemicals from spent liquors from an alkaline or neutral pulping process.

Sandborn, Lloyd T., and Nall, Dan M. Chemical recovery process. U. S. patent 2,913,310. Filed May 14, 1956. 10 claims. Assigned to Crossett Chemical Co. [Cl. 23-131.] Monocarboxylic acids are recovered from black liquor.

Schroeder, Carl W. Preparation of paper having improved wet strength. U. S. patent 2,913,356. Filed June 28, 1955. 14 claims. Assigned to Shell Devt. Co. [Cl. 117-155.] The pulp or paper is treated with a polyether polyepoxide and an epoxy curing agent, and then heated.

Showalter, Frank W. Adhesive applying device. U. S. patent 2,912,959. Filed June 9, 1955. 2 claims. Assigned to The American Envelope Co. [Cl. 118-5.] An envelope-gummer is provided.

Sottysiak, Joseph, and Proc, John. Preventing the aging of printing-out paper coatings. U. S. patent 2,913,339. Filed Dec. 31, 1956. 4 claims. Assigned to General Aniline Film Corp. [Cl. 96-78.]

Steigerwalt, Oliver I., and Oshry, Howard I. Method of making a printed circuit. U. S. patent 2,912,745. Filed Aug. 25, 1955. 1 claim. Assigned to Erie Resistor Corp. [Cl. 29-155.5.] Paper and foil layers are laminated together and embossed in the pattern of the circuit to be formed, the pattern also including soldering cup depressions.

Travis, Albert M. Plant package. U. S. patent 2,913,161. Filed June 15, 1953. 1 claim. Assigned to Waldorf Paper Prods. Co. [Cl. 229-22.] A paperboard box of triangular cross section is provided for packing potted plants.

Walther, Rüdolf E. Process and apparatus for the manufacture of folded cartons. U. S. patent 2,912,907. Filed Oct. 28, 1957. 8 claims. [Cl. 93-44.] The cartons formed are of the steam- and aroma-tight type used for packing cigarettes, frozen foods, and the like.

Weeks, Lloyd E. Detergent composition. U. S. patent 2,913,417. Filed Nov. 27, 1953. 9 claims. Assigned to Monsanto Chemical Co. [Cl. 252-152.] A detergent includes an alkylolamide of tall oil fatty acids.

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Alderman, Edwin N., Spearman, Elmer I., and Stout, Caleb M. Thickened petroleum liquid especially for treating wells. U. S. patent 2,914,476. Filed April 30, 1957. 5 claims. Assigned to The Dow Chemical Co. [Cl. 252-8.55.] Tall oil is used.

Budd, Larry J. Leg structure for pallet. U. S. patent 2,-914,282. Filed July 16, 1956. 7 claims. Assigned to Pallet Devices, Inc. [Cl. 248-120.] The pallet and the legs are formed of paperboard elements.

Butler, Robert W. Stabilized icings and preparation. U. S. patent 2,914,410. Filed Dec. 7, 1956. 4 claims. Assigned to Hercules Powder Co. [Cl. 99-139.] Sodium carboxymethylcellulose is used.

Clark, Jared W. Composite packaging units. U. S. patent 2,914,238. Filed May 28, 1958. 11 claims. Assigned to Union Carbide Corp. [Cl. 229-55.] A ply of polyol-impregnated paper is included in a multi-ply bag for packaging hydrocarbons such as kerosene.

Coakley, Lige. Seaming apparatus. U. S. patent 2,914,-108. Filed Feb. 7, 1955. 4 claims. Assigned to Bemis Bro. Bag Co. [Cl. 154-42.] A continuous multi-ply paper tube is formed for severing to make bags.

Cooper, Ronald H. Shell mold composition and method of making same. U. S. patent 2,913,787. Filed Sept. 26, 1956. 20 claims. Assigned to The Dow Chemical Co. [Cl. 22-193.] Lignin resins are used.

Crane, Samuel P. Mount for bicycle saddle cover. U. S. patent 2,914,168. Filed Aug. 9, 1957. 6 claims. Assigned to R. O. Kent Co. [Cl. 206-79.] The cover is mounted on a diecut paperboard card.

De Lap, Robert A. Stabilized ethyl cellulose compositions. U. S. patent 2,914,416. Filed Oct. 30, 1958. 15 claims. Assigned to The Dow Chemical Co. [Cl. 106-177.] The composition includes an antioxidant and is stabilized against high temperature discoloration.

Dgetluck, John. Display devices. U. S. patent 2,914,184. Filed April 10, 1958. 5 claims. Assigned to Pioneer Folding Box, Inc. [Cl. 211-55.] A multitiered display rack for playing cards is formed from paperboard.

Engleson, Harry E., and Sramek, E. D. Leaflet feeding mechanism. U. S. patent 2,914,322. Filed Oct. 25, 1956. 6 claims. Assigned to F. B. Redington Co. [Cl. 271-32.] The leaflets are fed to a packaging machine so that one is included in each pack formed.

Filsinger, Jamieson A., and Braun, Philip N. Apparatus for heat sealing identification tags to garments and the like. U. S. patent 2,914,208. Filed May 28, 1956. 4 claims. Assigned to Philip N. Braun. [Cl. 216-29.]

Gafner, Emil. Pulp wood loader. U. S. patent 2,914,203. Filed Jan. 9, 1958. 7 claims. [Cl. 214-147.] A tractor-mounted split boom pulpwood loader is provided.

Gaines, George L., Jr. Method of rendering mica paper moisture resistant and article produced thereby. U. S. patent 2,914,426. Filed Aug. 9, 1956. 4 claims. Assigned to General Elec. Co. [Cl. 117-118.]

Gaines, George L., Jr. Mica paper and method of preparing it. U. S. patent 2,914,107. Filed Sept. 24, 1956. 2 claims. Assigned to General Elec. Co. [Cl. 154-2.6.] The furnish is treated with potassium silicate; the paper has improved moisture resistance and tensile strength.

Goheen, David W., and Hearon, William M. Making methyl mercaptan from desugared spent sulfite pulping liquors. U. S. patent 2,914,567. Filed Dec. 6, 1957. 20 claims. Assigned to Crown Zellerbach Corp. [Cl. 260-609.]

Goheen, David W., Hearon, William M., Cisney, Merle E., and Wethern, James D. Making dimethyl sulfide from desugared spent sulfite pulping liquors. U. S. patent 2,914,568. Filed Dec. 6, 1957. 19 claims. Assigned to Crown Zellerbach Corp. [Cl. 260-609.]

Hassel, Lloyd V. Method of fabricating unbacked surface coverings. U. S. patent 2,913,773. Filed Nov. 6, 1956. 15 claims. Assigned to Armstrong Cork Co. [Cl. 18-59.2.] A special paper carrier web is used in forming vinyl floor coverings.

Hazelwood, James W. Folded liquid containing box. U. S. patent 2,914,234. Filed July 26, 1956. 2 claims. Assigned to Newth-Morris Box Corp. of Florida. [Cl. 229-31.]

Hestvik, Ole A., Olin, Fredrik R., Salmén, August L., and Söderberg, Bengt A. Apparatus for disintegration of wood materials. U. S. patent 2,914,259. Filed Dec. 26, 1956. 7 claims. Assigned to Aktiebolaget Celleco. [Cl. 241-46.] The apparatus fiberizes wood wastes and pulp screenings.

Holtz, Albert. Pressure sensitive adhesive tape and method of manufacture. U. S. patent 2,914,167. Filed March 26, 1956.

12 claims. Assigned to Johnson & Johnson. [Cl. 206-59.] A release coating is provided.

Irmscher, Hans O. Manufacture of packages with string handles and tags. U. S. patent 2,913,860. Filed March 1, 1949. 26 claims. Assigned to National Tea Packing Co., Inc. [Cl. 53-14.] A machine attaches tags to one end of a string and staples the other end to the closure seam of a tea bag.

Jones, Cecil T. Foldable interlocked boxes. U. S. patent 2,914,235. Filed May 31, 1956. 8 claims. Assigned to Container Corp. of America. [Cl. 229-34.] A lug or open top carton is provided with means for interlocking vertically adjacent boxes in a stack.

Kästli, Leo. Process of puffing dry regenerated cellulose and cellulose acetate textile fibers by generating oxygen in situ and precipitating barium sulfate within the fibers. U. S. patent 2,913,768. Filed July 6, 1953. 3 claims. [Cl. 18-48.]

King, Albert. Manufacture of microcrystalline wax impregnated electric cables. U. S. patent 2,914,429. Filed March 3, 1952. 10 claims. Assigned to British Insulated Callender's Cables, Ltd. [Cl. 117-231.] This is similar to U. S. patent 2,914,430 (Nov. 24, 1959).

King, Albert, and Collins, Kenneth J. Method of using low viscosity-low volatility mineral oil and wax in an insulated electric cable. U. S. patent 2,914,430. Filed Feb. 18, 1953. 7 claims. Assigned to British Insulated Callender's Cables, Ltd. [Cl. 117-231.] The oil and wax are used as impregnants for cable-insulating paper.

Koot, Paul. Cellulose sponge composition containing polyethylene terephthalate fiber and method of making. U. S. patent 2,914,493. Filed Feb. 4, 1957. 5 claims. Assigned to American Enka Corp. [Cl. 260-2.5.]

Kopp, Marvin. Heavy duty liquid detergent. U. S. patent 2,914,482. Filed June 11, 1956. 2 claims. Assigned to General Aniline & Film Corp. [Cl. 252-152.] Carboxymethylcellulose is used.

Levkoff, David. Cartons. U. S. patent 2,914,233. Filed Feb. 14, 1957. 5 claims. Assigned 25% to Evelyn S. Levkoff, 25% to Henry S. Levkoff, and 25% to Edith L. Sennet. [Cl. 229-16.] A traylike carton for bakery goods is provided with an interlocked reinforced side wall construction.

Limburg, Pieter C. Manufacture of viscose thread. U. S. patent 2,914,375. Filed April 25, 1955. 6 claims. Assigned to American Enka Corp. [Cl. 18-54.] Quinoline is used as coagulation modifier.

McGarvey, John A., and Schenck, Harold A., and Adamick, Jules R. Making signatures, booklets, pamphlets, and the like. U. S. patent 2,914,318. Filed May 12, 1958. 11 claims. Schenck's interest assigned to Adamick. [Cl. 270-32.]

Macneale, Neil. Multiple packages. U. S. patent 2,913,861. Filed Dec. 18, 1953. 4 claims. Assigned to Procter & Gamble Co. [Cl. 53-28.] A multicompartment paper packet for pharmaceutical preparations is provided.

Malhiot, Clarence J. Package stacking and sealing mechanism. U. S. patent 2,913,864. Filed June 5, 1956. (Divided; original May 20, 1950.) 10 claims. Assigned to F. B. Redington Co. [Cl. 53-387.] The adhesive seals in a wrapped carton are dried.

Malmad, Fred. Box structure. U. S. patent 2,914,237. Filed July 9, 1957. 4 claims. [Cl. 229-41.] A folding carton is provided with a reinforced bottom.

Mayson, Herbert. Paper stick for supporting confections and method of making the same. U. S. patent 2,914,409. Filed March 31, 1958. 4 claims. Assigned to Textilose, Ltd. [Cl. 99-138.]

Means, John A. Paper winding apparatus. U. S. patent 2,914,267. Filed Aug. 6, 1956. 9 claims. Assigned to Kalamazoo Vegetable Parchment Co. [Cl. 242-67.1.]

Nakielny, Felix G. Composite plastic article with a cellulose acetate component. U. S. patent 2,914,436. Filed Nov. 2, 1955. 6 claims. Assigned to Hercules Powder Co. [Cl. 154-43.] Crazing of other plastics in contact with cellulose acetate is prevented by using certain plasticizers in the cellulose acetate.

Novak, Leo J., and Hogue, Walter S. Shaped articles comprising regenerated cellulose. U. S. patent 2,914,414. Filed March 8, 1954. 10 claims. Assigned to The Commonwealth Eng. Co. of Ohio. [Cl. 106-162.] Reduced moisture pick-up and retention capacity are provided by including a dextran in the article.

Paschall, Eugene F. Preparation of starch esters. U. S. patent 2,914,526. Filed Aug. 2, 1956. 8 claims. Assigned to Corn Prods. Co. [Cl. 260-233.5.]

Reed, Ralph W., Rankin, Walter J., and Tungseth, Barry F. Rotative abrasive structure. U. S. patent 2,913,857. Filed June 26, 1957. 12 claims. Assigned to Minnesota Mining and Mfg. Co. [Cl. 51-193.5.] An abrasive wheel includes flaps of abrasive sheet material.

Richter, Ole J. Material feeding apparatus. U. S. patent 2,914,223. Filed March 10, 1958. 3 claims. Assigned to Aktiebolaget Kamyr. [Cl. 222-194.] Means are provided to introduce material into a continuous pressurized digester.

Scriven, Albert K., Jr. Carton construction and method of making the same. U. S. patent 2,913,967. Filed April 10, 1958. 8 claims. Assigned to S. Curtis and Son, Inc. [Cl. 93-26.] The end flaps of a carton are held in erected condition by a retaining strip secured to the panel adjacent the flap.

Shapiro, Martin D. Folding box construction. U. S. patent 2,914,236. Filed April 1, 1957. 1 claim. Assigned to Royal-Pioneer Paper Box Mfg. Co., Inc. [Cl. 229-34.] A display panel is provided.

Smith, David F. Cellulosic hemostatic composition. U. S. patent 2,914,444. Filed Dec. 12, 1950. 8 claims. [Cl. 167-65.] Carboxymethylcellulose and cellulose sulfuric acid esters are used.

Sramek, Elmer D. Carton unloader. U. S. patent 2,914,323. Filed Nov. 12, 1957. 3 claims. Assigned to F. B. Redington Co. [Cl. 271-32.] Collapsed cartons are fed to a packaging machine without marring any printing that is on the blank.

Sylvester, John D., Messmer, Edwin E., and Keenan, John D., Jr. Machine for forming edge seal closures on bags. U. S. patent 2,913,863. Filed March 19, 1958. 7 claims. Assigned to Amsco Pkg. Machinery, Inc. [Cl. 53-373.]

**Dec. 1, 1959**

Annable, Weldon G., and Jacobs, William L. Hydro-refining method for lubricating oils and wax using nickel molybdate or silver molybdate on alumina. U. S. patent 2,915,448. Filed May 25, 1956. 6 claims. Assigned to The Pure Oil Co. [Cl. 208-27.] Microcrystalline waxes are decolorized.

Arabian, Karekin G. Paraffin wax compositions having improved flexibility. U. S. patent 2,915,447. Filed Feb. 28, 1955. 4 claims. Assigned to Shell Devt. Co. [Cl. 208-21.] A coating wax includes normal nonadecane.

Barnhart, Adam B. Package for hosiery and other articles. U. S. patent 2,915,174. Filed Aug. 15, 1958. 2 claims. Assigned to Metric Hosiery Co., Inc. [Cl. 206-7.] The pack includes an inner paperboard supporting member and an outer film wrapper.

Bartay, Delmar M. Process for the preparation of hydrocarbon wax compositions. U. S. patent 2,915,451. Filed Sept. 16, 1957. 4 claims. Assigned to Shell Devt. Co. [Cl. 208-31.] Waxes of improved flexibility are prepared for coating milk cartons.

Benschoter, James C. Baling method and bale. U. S. patent 2,915,208. Filed June 8, 1953. 6 claims. Assigned to Fibreboard Paper Prods. Corp. [Cl. 214-152.] Carton blanks are baled into a form suitable for accepting the tines of a fork-lift truck.

Brennan, Andrew. Adhesive devices. U. S. patent 2,914,873. Filed Jan. 25, 1957. 3 claims. [Cl. 40-125.] A bulletin board comprises a paperboard backing coated with a nondrying adhesive wax.

Breunig, Jack E. Carton and handle structure. U. S. patent 2,915,236. Filed Oct. 30, 1956. 2 claims. Assigned to General Foods Corp. [Cl. 229-52.] A heavy wire handle element is provided for attachment to a carton carrying a heavy weight of material.

Flood, Carl A. String tags. U. S. patent 2,915,177. Filed Oct. 31, 1957. 2 claims. Assigned to Dennison Mfg. Co. [Cl. 206-56.] Tags (price and garment, etc.) are packaged by affixing the strings to adhesive tape.

Francis, Frederick G., and Neale, David J. Leucauramine derivate of benzoyl leuco methylene blue and transfer sheet coated therewith. U. S. patent 2,915,415. Filed June 5, 1958. 4 claims. Assigned to Caribonum, Ltd. [Cl. 117-36.]

Gibson, George A., Jr. Apparatus for feeding flat stock. U. S. patent 2,915,310. Filed Aug. 21, 1957. (Divided; original July 7, 1954.) 1 claim. [Cl. 271-62.]

Goodrich, Gordon W. Modular display arrangement. U. S. patent 2,914,872. Filed Aug. 27, 1957. 5 claims. Assigned to The Martin Co. [Cl. 40-124.] Paperboard panels on metal frames are assembled to form a variety of different large-size displays.

Hammond, John H., Jr., and Chaffee, Emory L. Frozen food indicator. U. S. patent 2,915,405. Filed March 17, 1958. 1 claim. Chaffee's interest assigned to Hammond, Jr. [Cl. 99-192.] A simple device is provided for indicating the amount of defrosting to which a frozen food carton has been subjected.

Hart, Edgar L., Jr., Whaley, Baynard R., and Turnage, Richard W. Paper tube for forming concrete columns and the like having an overlapped inner ply with a coating material thereon. U. S. patent 2,914,833. Filed Nov. 26, 1956. 2 claims. Assigned to Sonoco Prods. Co. [Cl. 25-118.]

Haugwitz, Otto. Machine for the production of packed coils of wire and the like. U. S. patent 2,914,897. Filed Jan. 28, 1957. 8 claims. Assigned to Societe Anonyme Geoffrey-Delore. [Cl. 53-118.] The machine coils wire, wraps the coil in paper, and tapes the package.

Hansen, Oscar A. Process and apparatus for separating the foremost one of a stack of nested cup-shaped caps from the remainder of the stack and conveying it to a position at a distance from the stack. U. S. patent 2,914,894. Filed March 19, 1957. 8 claims. [Cl. 53-38.]

Henschel, Joseph W. Cap packaging inserts. U. S. patent 2,915,231. Filed Dec. 12, 1956. 3 claims. [Cl. 223-84.] A paperboard device replaces the rolled tissue conventionally used as inserts in men's caps.

Justus, Edgar J., and Daane, Robert A. Drying drum and method. U. S. patent 2,915,293. Filed April 10, 1957. 8 claims. Assigned to Beloit Iron Works. [Cl. 257-95.] The low-pressure cylinder includes inner and outer shells with a heat-transfer oil maintained between the two.

Kinsley, Lewis H., Jr., and Anderson, John W. Capper. U. S. patent 2,914,901. Filed March 5, 1957. 4 claims. [Cl. 53-310.] A small device is provided to apply a paper cap to a filled paper cup.

Langdon, Arthur J. Wrap for surgical gloves. U. S. patent 2,915,173. Filed June 9, 1958. 7 claims. Assigned to Sterling Precision Corp. [Cl. 206-7.] A wrapperlike carton is provided.

Lyons, Sanford C. Method of handling and conditioning papermaking clay for use. U. S. patent 2,915,412. Filed March 15, 1957. 5 claims. Assigned to Georgia Kaolin Co. [Cl. 106-286.]

McAndrew, John F. Process of deashing cellulose ethers. U. S. patent 2,915,520. Filed July 9, 1956. 10 claims. Assigned to Hercules Powder Co. [Cl. 260-232.]

McGihon, Leonard. Carton feed mechanism. U. S. patent 2,915,309. Filed June 11, 1956. 4 claims. Assigned to King-O-Matic Equipment Corp. [Cl. 271-10.]

McGihon, Leonard. End carton filler. U. S. patent 2,914,-899. Filed Jan. 3, 1957. 8 claims. Assigned to King-O-Matic Equipment Corp. [Cl. 53-160.] Six-pack open end can cartons are filled.

McKay, David J., Jr., and Kimmel, Edwin N. Self-contouring bags. U. S. patent 2,915,098. Filed July 28, 1958. 4 claims. Assigned to Central States Paper & Bag Co. [Cl. 150-5.] Liquid or powdered chemicals are packaged in an inner plastic bag and an outer carton.

Martin, Samuel W. Envelope stuffing machine. U. S. patent 2,914,895. Filed Feb. 13, 1959. 17 claims. Assigned to Pitney-Bowes, Inc. [Cl. 53-59.]

Mendelsohn, Meyer. Separator for electric battery. U. S. patent 2,915,579. Filed Dec. 27, 1955. 6 claims. Assigned to Ions Exchange & Chemical Corp. [Cl. 136-146.] Regenerated cellulose membranes are used in forming battery cell separators.

Miller, William P. Doctor blade and control means therefor. U. S. patent 2,915,421. Filed Nov. 14, 1956. 8 claims. [Cl. 134-6.]

Miyamoto, Eitaro. Binder for filing covers. U. S. patent 2,915,068. Filed May 20, 1957. 3 claims. [Cl. 129-24.)

Olson, Robert J. Process for the preparation of hydrocarbon wax compositions comprising deoiling a blend of slack and soft waxes. U. S. patent 2,915,450. Filed Sept. 11, 1957. 5 claims. Assigned to Shell Devt. Co. [Cl. 208-31.] The compositions are of use in coating milk cartons or the like.

O'Neil, John G. Disposable drinking cup structure. U. S. patent 2,915,176. Filed Nov. 29, 1957. 2 claims. [Cl. 206-47.] A paper cup, including a wafer of beverage concentrate, is provided.

Phelps, Richard W. Paper machinery. U. S. patent 2,915,-255. Filed May 19, 1955. 8 claims. Assigned to The Black-Clawson Co. [Cl. 242-56.] Improved roll-changing means are provided in a paper web winder.

Poelman, Armand J. J. Filter device and method for making a filter device. U. S. patent 2,915,426. Filed Sept. 11, 1956. 7 claims. [Cl. 154-93.] The pleats in a pleated filter are spaced apart by fiber strands.

Popeck, Stanley P., and Sottysiak, Joseph R. Antifogging agents for light sensitive paper emulsions. U. S. patent 2,915,-395. Filed Feb. 15, 1957. 5 claims. Assigned to General Aniline & Film Corp. [Cl. 96-85.]

Ragan, Robert O., and Trant, Robert F. Nonblocking adhesive sheet. U. S. patent 2,915,413. Filed June 13, 1955. 13 claims. Assigned to United Biscuit Co. of America. [Cl. 117-15.] The sheet comprises waxed paper or waxed board over the surface of which is deposited a pattern of nonfibrous nonblocking material consisting of titanium dioxide and nitrocellulose.

Rosenmann, Abraham W., and Greisner, Rudolf F. Container and receptacle for tissues. U. S. patent 2,915,218. Filed July 12, 1956. 4 claims. [Cl. 221-102.]

Rueckert, Dean E. Container for frozen foods. U. S. patent 2,915,235. Filed Oct. 29, 1956. 1 claim. Assigned to Swift & Co. [Cl. 229-23.] A paperboard container is designed to hold frozen foods and ice during shipment.

Rumsey, Herbert, Jr. Apparatus for wrapper end closure. U. S. patent 2,914,898. Filed May 28, 1956. 4 claims. Assigned to W. R. Grace & Co. [Cl. 53-141.] A crimped heat-sealed is applied to the ends of a pack wrapped in heat-sealable material.

Salerno, Joseph R. Feed mechanism for containers. U. S. patent 2,915,219. Filed March 15, 1955. 6 claims. [Cl. 221-113.] An ice cream vending machine is provided with means for feeding the containers to the dispensing head.

Schneider, Alfred. Dry size and method of making the same. U. S. patent 2,915,410. Filed Feb. 3, 1958. 7 claims. Assigned to A. Schneider G.m.b.H. [Cl. 106-239.] Rosin is mixed with kerosene and sodium aluminate.

Schur, Milton O. Smoking device. U. S. patent 2,915,069. Filed July 13, 1954. 1 claim. Assigned to Olin Mathieson Chemical Corp. [Cl. 131-10.] A cigarette filter is formed from creped paper sheeted from a furnish including activated charcoal.

Senter, Florence. Display liners for dresses or the like. U. S. patent 2,915,228. Filed March 23, 1956. 3 claims. [Cl. 223-68.] The liner is of paper.

Smith, Eric, and Scholes, Thomas. Doctor knives. U. S. patent 2,914,788. Filed March 4, 1958. 7 claims. Assigned to D.S.T. Pattern and Eng. Co. Ltd. [Cl. 15-256.5.]

Smith, Paul, and Smith, Arthur J. Surprise calendars. U. S. patent 2,914,871. Filed Oct. 16, 1957. 1 claim. [Cl. 40-107.] A cellular toy carton is mounted behind a calendar sheet, with the sections of the sheet corresponding with the underlying cells of the carton.

Stein, Elmer L. Advertising displays. U. S. patent 2,914,-874. Filed Feb. 8, 1957. 3 claims. Assigned to Eye-Beam Displays, Inc. [Cl. 40-125.] An assembly of paperboard elements mounts on the top of a bottle.

Stewart, William D., Pondexter, Edward, Jr., and Wachtel, William L. Processing cellulose nitrate. U. S. patent 2,915,519. Filed Sept. 28, 1954. 17 claims. Assigned to Atlantic Research Corp. [Cl. 260-223.]

Straw, Douglas. Diazotypes containing 2,2′-alkylene-bis-(1,3-cyclohexanediones) as azo components. U. S. patent 2,915,-396. Filed July 16, 1957. 6 claims. Assigned to General Aniline & Film Corp. [Cl. 96-91.]

Then, Edward O. Carrying device for containers. U. S. patent 2,914,826. Filed Dec. 23, 1955. 2 claims. Assigned to American Can Co. [Cl. 24-17.] A paper band and separate handle device are provided for unitizing two flat-top paper milk cartons.

Wallenberg, Fritz. Roller positioning apparatus for coating machines. U. S. patent 2,915,038. Filed June 27, 1957. 4 claims. Assigned to General Aniline & Film Corp. [Cl. 118-249.]

Weinberg, Elliott L. Process for controlling slime in papermaking systems and products therefrom. U. S. patent 2,915,428. Filed Feb. 10, 1956. 16 claims. Assigned to Metal & Thermit Corp. [Cl 162-161.] Bis(tributyltin) oxide is added to the pulp.

Wenker, Henry. Indicator papers. U. S. patent 2,915,373. Filed July 20, 1959. 4 claims. [Cl. 23-253.] Various quaternary ammonium bases are used as dye-fixing agents in a pH indicator paper.

Wolfrom, Robert E. Nonwoven fibrous products. U. S. patent 2,915,418. Filed Nov. 21, 1956. 19 claims. Assigned to Rohm & Haas Co. [Cl. 117-140.] A polyester-aminoplast binder is provided.

Zalkind, Joseph. Device for separating and sorting manifold sets. U. S. patent 2,915,234. Filed Oct. 19, 1955. 7 claims. [Cl. 225-101.]

Zinkowski, Charles N. Device for packaging materials. U. S. patent 2,914,896. Filed March 18, 1959. 10 claims. Assigned to Republic Aviation Corp. [Cl. 53-78.] The machine wraps small items such as bolts and springs.

**Dec. 8, 1959**

Alger, John. Refreshment plate holders. U. S. patent 2,916,-180. Filed April 21, 1958. 2 claims. [Cl. 220-23.86.] A molded device is provided to permit supporting a paper plate, cup, and napkin in one hand.

Altmann, Norman A., and Bureau, William H. Method and apparatus for preparing papermaking stock. U. S. patent 2,916,-216. Filed July 25, 1952. 4 claims. Assigned to Butler Co. [Cl. 241-20.] Waste paper stock is prepared.

Altmann, Norman A., and Bureau, William H. Method of deinking waste paper. U. S. patent 2,916,412. Filed Nov. 17, 1953. 5 claims. Assigned to Butler Co. [Cl. 162-4.]

Anderson, Swan F., and Anderson, Ralph F. Bar forming and wrapping machine. U. S. patent 2,915,865. Filed July 7, 1954. 40 claims. [Cl. 53-122.] Ice cream bars are formed and wrapped in open-end paper tubes.

Bartlo, John S. Product settling means for draw type wrapping machine. U. S. patent 2,915,866. Filed May 12, 1958. 7 claims. Assigned to Lynch Corp. [Cl. 53-124.]

Buchen, Joseph C. Sifter device and means for attaching sifter and other plastic members to flat sheet members or cartons.

U. S. patent 2,916,191. Filed Oct. 30, 1956. 1 claim. Assigned to Leslie Salt Co. [Cl. 222-555.]

Carkhuff, Le Roy F. Printing attachment for machine. U. S. patent 2,915,963. Filed Dec. 24, 1957. 4 claims. Assigned to Diamond Gardner Corp. [Cl. 101-35.] A printing device is provided for attachment to machines processing cartons.

Clemons, Dale R. Methods of making electrical capacitors. U. S. patent 2,915,808. Filed April 9, 1956. 1 claim. Assigned to Western Elec. Co., Inc. [Cl. 29-25.42.]

Copping, Bruce G. Four flap case opener. U. S. patent 2,915,868. Filed Dec. 30, 1957. 18 claims. Assigned to Akron, Inc. [Cl. 53-381.]

Cross, Carroll N., and Hayhow, Cyril D. Collapsible stand. U. S. patent 2,916,236. Filed Nov. 7, 1957. 5 claims. Assigned to Ad-A-Day Co., Inc. [Cl. 248-35.] A paper board easel-type stand is provided for supporting a calender pad or the like.

Cross, Carroll, N., and Hayhow, Cyril D. Collapsible stand. U. S. patent 2,916,242. Filed Sept. 25, 1958. 6 claims. Assigned to Ad-A-Day Co., Inc. [Cl. 248-198.] A paperboard easel-type stand is provided for supporting a calender pad or the like.

Detrie, Arthur J., Lingenfelter, Daniel J., O'Neil, Eugene J., Stayboldt, Paul J., and Troeger, Edgar P. Compartmented container. U. S. patent 2,916,197. Filed May 6, 1957. 10 claims. Assigned to Douglas Aircraft Co., Inc. [Cl. 229–56.] A compartmented bag is provided for packing two-component adhesives or the like.

Frank, Anton R., and Giles, William H. Wrapping machines. U. S. patent 2,915,867. Filed May 13, 1955. 2 claims. Assigned to Van Buren Machine Corp. [Cl. 53-230.] The machine wraps cakes of soap in special paper wrappers.

Frankenstein, William P. Carton. U. S. patent 2,916,194. Filed April 8, 1954. 1 claim. [Cl. 229-33.] A flat one-piece paperboard hollow-wall hinged-cover box is provided.

Fraser, George L., and Elmer, Curtis. Internally plasticized melamine resins. U. S. patent 2,916,410. Filed Nov. 12, 1953. 11 claims. Assigned to Monsanto Chemical Co. [Cl. 154-43.] This is a paper-laminating resin.

Gaitten, Walden M. Log conveying system for a debarking machine. U. S. patent 2,916,064. Filed Sept. 26, 1956. 10 claims. Assigned to Soderhamn Machine Mfg. Co. [Cl. 144-247.]

Gatward, Harry F. Box-like cartons. U. S. patent 2,916,195. Filed Jan. 10, 1957. 2 claims. [Cl. 229-52.] A handled paperboard carton for four bottles is provided.

George, Walter C. Box fabricating mandrel. U. S. patent 2,915,951. Filed Nov. 7, 1955. 5 claims. [Cl. 93-59.] A mandrel is provided to facilitate the manual erection of paperboard bottle cases.

Gregory, Thurlow G. Cord-reinforced cellulose sponge material. U. S. patent 2,916,390. Filed May 5, 1958. 4 claims. [Cl. 106-164.]

Gross, Theodore J. Device for simultaneously cutting the corners of a box to provide closure flaps. U. S. patent 2,915,932. Filed Jan. 15, 1957. 6 claims. Assigned to Union Bag-Camp Paper Corp. [Cl. 83-440.]

Hansen, George C. Disposable diaper. U. S. patent 2,916,-037. Filed Nov. 19, 1956. 2 claims. [Cl. 128-284.]

Harpham, John A. Paper manufacture. U. S. patent 2,916,-413. Filed April 15, 1957. 12 claims. Assigned to Hercules Powder Co. [Cl. 162-157.] Paper strength is improved by using cotton linters which have been hydroxyethylated.

Hebert, Walter W., Jr. Apron taper. U. S. patent 2,916,078. Filed Aug. 27, 1954. 1 claim. Assigned to Minnesota Mining & Mfg. Co. [Cl. 154-1.6.] An apparatus for masking articles for painting adheres masking tape along the margin of a paper sheet and in overlapping relation thereto without wrinkling the paper or tape.

Hees, Walter. Process for dyeing articles of polyethylene terephthalate or cellulose triacetate. U. S. patent 2,916,345. Filed Dec. 19, 1957. 4 claims. Assigned to Farbenfabriken Bayer A.G. [Cl. 8-36.]

Hollihan, John P., Jr., Howsmon, John A., and Sisson, Wayne A. Process of producing viscose rayon. U. S. patent 2,916,391. Filed Jan. 2, 1958. (Divided; original Nov. 3, 1954.) 6 claims. Assigned to American Viscose Corp. [Cl. 106-165.] The coagulation modifiers used are alkylene oxide adducts of amino fatty alkyl amides.

Jalkanen, Matti J. Method for chemical treatment of suspended solids. U. S. patent 2,916,346. Filed Oct. 6, 1953. 3 claims. Assigned to Rauma-Repola Oy. [Cl. 8-156.] A method is provided for continuously treating (bleaching) wood pulp with chemicals, in which treatment and subsequent washing take place in the same vessel.

Kramer, Joseph, and Struble, Glenn E. Box. U. S. patent 2,916,196. Filed March 5, 1957. 3 claims. Assigned to The Diamond Gardner Corp. [Cl. 229-52.] A collapsible handle is provided in a shoe box.

Kritchever, Mathew F. Electrostatic discharge treating apparatus. U. S. patent 2,916,620. Filed Oct. 26, 1956. 5 claims. Assigned 25% to Horace Dawson. [Cl. 250-49.5.] The surfaces of web materials are treated, for example, polyethylene is treated to improve its adherence to ink, adhesive, etc.

Kummer, Ernst W. Apparatus for handling and filling envelopes. U. S. patent 2,915,863. Filed Nov. 15, 1954. 10 claims. [Cl. 53-117.]

Kummer, Ernst W. Automatic sheet folding and envelope feeding machine. U. S. patent 2,915,864. Filed Sept. 7, 1955. 12 claims. [Cl. 53-117.] The folded sheets are inserted in the envelopes.

La Bombard, Leon E. Method and mechanism for squaring-up boxes. U. S. patent 2,915,950. Filed April 21, 1958. 13 claims. [Cl. 93 36.]

Müller, Paul A. Filter for tobacco smoke. U. S. patent 2,916,039. Filed Jan. 22, 1957. 7 claims. [Cl. 131-208.] A cord for subdivision into filters is formed of a layer of pleated paper and a layer of fibers mechanically held to the paper.

O'Neil, John G. Apparatus for forming containers. U. S. patent 2,915,952. Filed Dec. 24, 1953. 8 claims. Assigned to Safe-Pack Container Co. [Cl. 93-82.] A cylindrical paperboard tube for use in making containers is formed.

Owen, Richard. Heat-sensitive copy-paper. U. S. patent 2,916,395. Filed July 21, 1958. 3 claims. Assigned to Minnesota Mining and Mfg. Co. [Cl. 117-36.]

Prescott, Merton W. Printing attachment for paper dispenser. U. S. patent 2,915,971. Filed May 15, 1956. 3 claims. [Cl. 101-213.] A device for dispensing wrapping paper from a roll is provided with means to print indicia onto the paper.

Ross, Sidney D. Dielectric compositions. U. S. patent 2,916,680. Filed Dec. 7, 1955. 3 claims. Assigned to Sprague Elec. Co. [Cl. 317-258.] A capacitor paper is described.

Rother, Richard J., Sr., and McManus, Albert R. Asphalt release coating. U. S. patent 2,916,466. Filed Feb. 6, 1957. 2 claims. Assigned to Crown Zellerbach Corp. [Cl. 260-17.4.] The inner surface of containers for asphalt is coated.

Schiefer, Ernest H. Portable hand tape folder. U. S. patent 2,916,079. Filed Dec. 18, 1957. 5 claims. [Cl. 154-1.8.] The device folds a length of adhesive tape about the marginal edges of a sheet of fiberboard or the like.

Swenson, Leonard K. Method of removing monovalent base ions from sulfite pulping liquors. U. S. patent 2,916,355. Filed Nov. 16, 1955. 9 claims. Assigned to J. F. Pritchard & Co. [Cl. 23-129.]

Vaughan, Frank C. Disposable toothbrushes. U. S. patent 2,915,767. Filed April 24, 1958. 6 claims. [Cl. 15-167.] Paper tape and a paper wrapper are used in the construction.

Villoresi, Camillo. Composite packing paper. U. S. patent 2,916,411. Filed Nov. 3, 1955. 5 claims. Assigned to Societa per Azioni Fabriche Fiammiferi ed Affini. [Cl. 154-55.] Two sheets of corrugated are laminated; one sheet can be stretched to maximum while the other retains a cushioning thickness.

Villoresi, Camillo. Method and machine for making composite packing paper. U. S. patent 2,916,080. Filed Nov. 8, 1957. (Divided; original Nov. 3, 1955.) 7 claims. Assigned to Societa per Azioni Fabriche Fiammiferi ed Affini. [Cl. 154-31.] The machine makes the paper described in U. S. patent 2,916,411 (Dec. 8, 1959).

Voullaire, Izak J. Method and means for the wrapping of articles such as fruit with paper. U. S. patent 2,915,861. Filed Jan. 27, 1958. 16 claims. [Cl. 53-34.]

Wade, Worth. Tobacco smoke filter. U. S. patent 2,916,038. Filed Feb. 23, 1954. 10 claims. Assigned to American Viscose Corp. [Cl. 131-10.] A cigarette filter is formed from a mixture of fibers including plastic fibers which carry an electric charge.

Whiteford, Errington A., and Birren, Faber. Books. U. S. patent 2,916,304. Filed Nov. 23, 1956. 2 claims. Assigned to Whiteford Paper Co., Inc. [Cl. 283-63.] Colored paper and colored ink of the same hue are used in making a book of enhanced eye appeal.

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Agulnick, Arnold. Flat gummed paper. U. S. patent 2,917,-396. Filed Oct. 25, 1957. 2 claims. Assigned to Dennison Mfg. Co. [Cl. 106-128.]

Anderson, Andrew W. Package sealing means. U. S. patent 2,916,865. Filed March 7, 1957. 5 claims. Assigned to Scandia Pkg. Machinery Co. [Cl. 53-379.] A cellophane overwrap is sealed about a compartmented traylike container.

Baker, Paul W., and Wolff, Walter M. Display package. U. S. patent 2,917,163. Filed Sept. 18, 1958. 3 claims. Assigned to Holeproof Hosiery Co. [Cl. 206-46.] A hosiery pack includes a display container which grips the ends of the folded hose in a positive manner.

Biel, Hans. Automatic paper working machine. U. S. patent 2,917,307. Filed May 6, 1955. 5 claims. Assigned to Hans Sickinger. [Cl. 270-37.] The machine prints, folds, and stitches paper to form school exercise books.

Bonzagni, Francis A., Cohen, Oscar P., and Markhart, Albert H. Thermosetting resins and high wet strength papers prepared therefrom. U. S. patent 2,917,427. Filed Dec. 14, 1955. 9 claims. Assigned to Monsanto Chemical Co. [Cl. 162-167.]

Bostock, Raymond N. Carrier for bottles and the like. U. S. patent 2,917,220. Filed March 5, 1958. 8 claims. Assigned to P. Ballentine & Sons. [Cl. 229-23.]

Bugosh, John. Felted products and processes containing fibrous boehmite. U. S. patent 2,917,426. Filed Sept. 26, 1958. 20 claims. Assigned to E. I. du Pont de Nemours & Co. [Cl. 162-145.] Inclusion of boehmite increases the strength of paper and other products.

Caldwell, Carlyle G., and Wurzburg, Otto B. Cold water soluble amino alkyl ethers of starch. U. S. patent 2,917,506. Filed Nov. 21, 1956. 12 claims. Assigned to National Starch and Chemical Corp. [Cl. 260-234.] These are of use as pulp additives.

Coover, Harry W., Jr., and Wooten, Willis C., Jr. Stabilized lower fatty acid esters of cellulose. U. S. patent 2,917,398. Filed Oct. 9, 1957. 10 claims. Assigned to Eastman Kodak Co. [Cl. 106-169.] Sulfur compounds such as chlorothiophenol are used to prevent discoloration and degradation.

Despres, Urban H. Individual serving pack. U. S. patent 2,917,216. Filed Sept. 25, 1957. 4 claims. Assigned to Keyes Fibre Co. [Cl. 229-2.5.] A compartmented container for ice cream or the like is formed of molded pulp.

Diesbach, Frederick B. Manifolding stationery. U. S. patent 2,917,324. Filed May 28, 1958. 1 claim. Assigned to Paul Benninghofen and F. B. Diesbach. [Cl. 282-3.] Stretching of interleaved carbons takes place when the pack is clamped into an autographic register.

Evans, Clifford, and Rack, George de Rome. Manufacture of linoleum. U. S. patent 2,917,399. Filed June 10, 1957. 15 claims. Assigned to Imperial Chemical Industries Ltd. [Cl. 106-228.] The composition includes a modified rosin cement and cork or wood flour.

Faeber, Harry W. Mechanism for separating bound and unbound books. U. S. patent 2,917,168. Filed Dec. 13, 1955. 14 claims. Assigned to Time, Inc. [Cl. 209-72.]

Forrer, Homer W. Four-cell compartmented carton. U. S. patent 2,917,202. Filed Oct. 10, 1956. 3 claims. Assigned to Mead Pkg., Inc. [Cl. 220-113.] A four-cell carton for bottles includes a handle member and double thickness partitions.

Frankenstein, William P. Carton. U. S. patent 2,917,222. Filed Feb. 15, 1957. 6 claims. [Cl. 229-41.] A hexagonal subdivisible separate-lid reinforced bottom ice cream carton is provided.

Gasior, Joseph F., and Greiff, Robert. Tube crimping machine. U. S. patent 2,916,975. Filed June 1, 1956. 13 claims. Assigned to Congoleum-Nairn, Inc. [Cl. 93-55.1.] End closures are applied to large paper tubes containing rolls of floor-covering materials.

Gregory, Joseph M., and Smith, Frank E. Mobile pack. U. S. patent 2,917,167. Filed Sept. 12, 1957. 1 claim. Assigned to Designed Prods., Ltd. [Cl. 206-65.] A number of cut-out articles are attached together with string so as to form a mobile when suspended, and the assembly is packed in a flat paperboard carton.

Guyer, Reynolds. Combination carton and cooking receptacle. U. S. patent 2,917,218. Filed June 22, 1955. 4 claims. Assigned to Waldorf Paper Prods. Co. [Cl. 229-23.]

Humphrey, Norman J. Paper and coin container. U. S. patent 2,917,224. Filed April 11, 1955. 2 claims. Assigned to Bankit Container Co. [Cl. 229-72.] An envelope with various pockets is provided for use in making deposits at a drive-in bank.

Kehr, Abraham B. Compartmented package. U. S. patent 2,917,164. Filed Oct. 31, 1956. 3 claims. Assigned to Kehr Prods. Co. [Cl. 206-47.] A paper bag for popsicles or the like has an integral separate pouch for a give-away item.

Klein, Clarence F. Method of opening and resealing a carton. U. S. patent 2,916,859. Filed July 1, 1957. (Divided; original Feb. 8, 1954.) 1 claim. Assigned to The Lord Baltimore Press, Inc. [Cl. 53-21.] A cigarette carton is designed for neat opening for tax-stamping, and resealing.

Kress, Bernard H. Process of treating cellulosic fabric and the product resulting therefrom. U. S. patent 2,917,411. Filed June 12, 1957. 2 claims. Assigned to Quaker Chemical Prods. Corp. [Cl. 117-139.4.] A paper wet-strength agent is provided.

Kucklinsky, Frederick W., and Farnow, Arthur D. Mechanism for feeding and setting up collapsed cartons. U. S. patent 2,916,974. Filed Oct. 30, 1957. (Divided; original Aug. 15, 1955.) 3 claims. Assigned to Container Equipment Corp. [Cl. 93-53.]

Le Bolt, John M., Minow, Lawrence I., and Stritoff, Martin, Jr. Nonslip bag. U. S. patent 2,917,223. Filed Oct. 19, 1955. 7 claims. Assigned to The Cromwell Paper Co. [Cl. 229-53.] The outer surface of a paper bag is embossed to prevent slipping when filled bags are stacked.

Lehmann, Harry. Device and method for closing and sealing containers. U. S. patent 2,916,861. Filed March 26, 1952. 3 claims. [Cl. 53-42.] A disk closure is applied to round nesting paper containers.

Leighton, Charles R., and Buck, James W. Bag tying machine. U. S. patent 2,916,863. Filed Dec. 9, 1954. 14 claims. [Cl. 53-135.]

Lidgard, Edward J. Packaging device for the individual window or the like. U. S. patent 2,917,166. Filed Oct. 7, 1957. 5 claims. Assigned to Flotopak Corp. [Cl. 206-62.] A cushioned windshield pack is provided.

Meissner, William E. Packaging apparatus. U. S. patent 2,916,864. Filed Dec. 2, 1957. 15 claims. Assigned to American Viscose Corp. [Cl. 53-180.] The machine extrudes butter or the like into a tube of packaging material and continuously forms the tube into individual packages.

Melchoni, Anna F., Johnson, Joyce L., and Chase, Vernon L. Composition comprising methyl cellulose, resin binder, amine salt and organic solvent and method of preparing oil-in-water emulsion therefrom. U. S. patent 2,917,475. Filed July 27, 1956. 2 claims. Assigned to Interchemical Corp. [Cl. 260-15.] This is a vehicle for a textile-printing paste.

Morgan, Burton D. Pre-cut self-adhesive stencil. U. S. patent 2,917,998. Filed Nov. 1, 1955. 2 claims. Assigned to Avery Adhesive Prods., Inc. [Cl. 101-128.1.]

Otto, Stuart. Electromagnetic packaging apparatus. U. S. patent 2,916,862. Filed July 13, 1956. 26 claims. [Cl. 53-55.] Magnetic means align nails as they are being cartoned.

Pattilloch, Donald K. Electrical insulating paper containing polymethyloyl phenol. U. S. patent 2,917,425. Filed May 1, 1957. 16 claims. Assigned to Michigan Research Laboratories, Inc., and to Electro-Chem Fiber Seal Corp. [Cl. 162-138.] The furnish is first treated with glyoxal, then with the phenol.

Polleys, Richard W. Pulping apparatus and method. U. S. patent 2,917,245. Filed April 24, 1957. 9 claims. Assigned to John W. Bolton & Sons, Inc. [Cl. 241-15.] Water jets are used to pulp waste paper without shortening the fibers.

Psaty, Leon A., Hunt, Robert E., and Blurton, Victor B. Article of manufacture. U. S. patent 2,917,215. Filed March 15, 1956. 5 claims. [Cl. 229-1.5] A cuplike container formed of a foil-paper laminate is designed so that the side seam involves paper to foil contact.

Reinhardt, Robert M., Mazzeno, Laurence W., Jr., and Reid, John D. Process for the production of cellulosic textiles with permanent creases and improved soil and abrasion resistance. U. S. patent 2,917,412. Filed May 12, 1958. 3 claims. Assigned to U. S. Secretary of Agr. [Cl. 117-139.4.]

Risdon, Harold L. Multipurpose container. U. S. patent 2,917,221. Filed Jan. 31, 1957. 12 claims. Assigned to The Pillsbury Co. [Cl. 229-34.] A carton formed of a board-foil laminate holds the dry ingredients of a baking mix and may be used as a mixing bowl and baking pan.

Salomon, Jacob. Pivotally mounted reciprocating cutter for a continuously moving suctionally held web. U. S. patent 2,916,956. Filed June 14, 1956. 8 claims. [Cl. 83-163.]

Sanford, Roy S. Carton sealing. U. S. patent 2,916,860. Filed Dec. 2, 1955. 9 claims. Assigned to Roy S. Sanford & Co. [Cl. 53-38.] A method is provided for gluing the top flaps of cartons, using the inertia of the carton contents to provide outward pressure.

Schimel, Irving. Container. U. S. patent 2,917,219. Filed Dec. 16, 1955. 9 claims. Assigned to Owens-Illinois Glass Co. [Cl. 229-23.] A carton with telescoping cover is set up by interlocking from blanks cut with minimum of waste.

Sisson, James B. Foamed polystyrene article. U. S. patent 2,917,217. Filed April 30, 1956. 14 claims. Assigned to St. Regis Paper Co. (Cl. 229-4.5.] A material for making containers comprises a foamed polystyrene sheet attached to a paper sheet.

Streed, William R. Slab-debarker having blade carrying members biased to engage the sides of the slab. U. S. patent 2,917,090. Filed Jan. 22, 1959. 11 claims. Assigned to Machine Prods. Co. [Cl. 144-208.]

Welsh, Richard F., Jr. Blasting assembly. U. S. patent 2,916,992. Filed June 11, 1956. 4 claims. Assigned to E. I. du Pont de Nemours and Co. [Cl. 102-22.] A carton for an explosive composition is formed so it may be easily mounted on the end of a pole for insertion into the correct blasting position.

Wilcox, Clifton P. Cellulosic pellicle and method of preparation. U. S. patent 2,917,397. Filed April 11, 1957. 6 claims. Assigned to E. I. du Pont de Nemours and Co. [Cl. 106-168.] Regenerated cellulose and the like is softened and dimensionally stabilized with hexylene glycol.

Wolff, George M., and Richardson, Charles D. Composite mica paper, mica flake electrical insulating material. U. S. patent 2,917,570. Filed April 25, 1957. 10 claims. Assigned to General Electric Co. [Cl. 174-120.]

**Dec. 22, 1959**

Aronson, Theodore F., and Lyon, Floyd A. Sheet handling

and laminating device. U. S. patent 2,918,278. Filed Nov. 20, 1957. 11 claims. Assigned to Halm Instrument Co., Inc. [Cl. 271-8.] A sheet-handling device for a printing press moves sheets into an overlapping stream.

Boje, Herbert H., and Schulz, August. Hydraulically actuated pressure foot for wood grinders. U. S. patent 2,918,039. Filed Aug. 14, 1957. 8 claims. Assigned to Armstrong Cork Co. [Cl. 121-1.]

Buck, Cecil S. Packaging machine. U. S. patent 2,917,882. Filed Oct. 16, 1958. 13 claims. Assigned to Adolph Coors Co. [Cl. 53-159.] The machine arranges a number of cartons into a group, then encases the group in an outer carton.

Butterfield, Louis M. Display carton for fruit and vegetables. U. S. patent 2,918,204. Filed July 15, 1957. 7 claims. [Cl. 229-2.5.] A traylike carton may be subdivided into sections.

Carlson, Harry A. Bookbinding strips. U. S. patent 2,918,-066. Filed Oct. 27, 1958. 5 claims. [Cl. 129-19.] The strips are adhered to separate sheets and then interlocked to bind the sheets in book form.

Clapp, Charles C. Packaging machine. U. S. patent 2,917,-976. Filed July 23, 1956. 16 claims. Assigned to Weyerhaeuser Timber Co. [Cl. 53-14.] A paperboard wrapper blank is applied about several artificial fireplace logs.

Cooper, Robert H., and Godfrey, Kenneth L. Composition containing benzothiazyl disulfide dispersed in a mineral oil. U. S. patent 2,918,512. Filed Nov. 1, 1954. 3 claims. Assigned to Monsanto Chemical Co. [Cl. 260-785.] Methylated tall oil is employed as an additive in the composition for use as a rubber-vulcanization accelerator.

Dorland, Roger M., Yan, Maxwell M., and Heslop, Elliot G. Artificial board. U. S. patent 2,918,398. Filed July 6, 1955. 9 claims. Assigned to Abitibi Corp. [Cl. 162-132.] Tall oil is used as a binder.

Eichmeier, Russell R. Stereotype dry mat. U. S. patent 2,918,399. Filed Jan. 4, 1956. 9 claims. Assigned to Burgess Cellulose Co. [Cl. 162-181.] Improved plasticity is provided by replacing a portion of the filler with a synthetic inorganic zeolite gel.

Fisher, John V. Multiple container package carrier device and packaging method. U. S. patent 2,917,877. Filed Oct. 8, 1956. 8 claims. Assigned 20% to Larry Crosby and 20% to Kenneth M. Crawford. [Cl. 53-14.] A six-pack can carrier is provided.

Freynik, Henry S. Fourdrinier wire belt, wire, and alloy composition thereof. U. S. patent 2,918,094. Filed April 12, 1957. 18 claims. Assigned to H. K. Porter Co. [Cl. 139-425.]

Frohbach, Harold O., Gill, Earle F., Marran, John S., and Romano, Anthony J. Tape dispenser. U. S. patent 2,918,189. Filed July 8, 1957. 3 claims. Assigned to Chart-Pak, Inc. [Cl. 216-20.] The device affixes very narrow pressure-sensitive tapes to a flat surface.

Gage, Thomas B. Process of extruding viscose wherein a formaldehyde containing acid bath solution is contacted with activated charcoal. U. S. patent 2,918,348. Filed Sept. 23, 1957. 4 claims. Assigned to E. I. du Pont de Nemours and Co. [Cl. 18-54.]

Graham, Galen E. Fast-curing linoleum composition. U. S. patent 2,918,441. Filed June 25, 1956. 18 claims. Assigned to Armstrong Cork Co. [Cl. 260-19.] A tall oil-based cement is included.

Hand, Leslie T., and Macy, Josiah N. Method of and apparatus for forming folded paper stacks. U. S. patent 2,918,277. Filed Nov. 27, 1956. 10 claims. [Cl. 270-73.] A wide stack of slit and zigzag folded paper is separated into narrow stacks, thus forming folded business machine tapes.

Hornberger, Clarence L. Pressure mechanism for wood grinders and the like. U. S. patent 2,918,224. Filed April 3, 1957. 4 claims. Assigned to Armstrong Cork Co. [Cl. 241-282.]

Hurley, Richard H., and Rowe, Stewart. Packaged foodstuffs. U. S. patent 2,918,377. Filed Jan. 16, 1956. 1 claim. Assigned to The Procter & Gamble Co. [Cl. 99-171.] A plastic bag in a carton forms a pack for a dry cake mix in which the bag may be used as a mixing vessel for mixing in liquids.

Jackson, Donald R. P. Apparatus for packing rectangular block-shaped articles. U. S. patent 2,917,887. Filed April 14, 1958. 1 claim. Assigned to Molins Machine Co. Ltd. [Cl. 53-230.] Cigarette packs are cartoned.

Jackson, Donald R. P. Apparatus for packing rectangular block-shaped articles in cartons. U. S. patent 2,918,279. Filed April 14, 1958. 2 claims. Assigned to Molins Machine Co. Ltd. [Cl. 271-28.] A filled cigarette carton is formed.

Kleingers, Alfred B., Jr. Handle structures for boxes and method of fabricating same. U. S. patent 2,918,206. Filed Oct. 18, 1955. 7 claims. Assigned to The Interstate Folding Box Co. [Cl. 229-52.] A paperboard handle with three-dimensional form may be made separately or integrally with the carton.

Leone, Salvatore J. Display stands. U. S. patent 2,918,178. Filed April 8, 1958. 7 claims. Assigned to The New Haven Board and Carton Co. [Cl. 211-178.] A paperboard display stand has a number of article-supporting pockets on the display face.

Lewis, Donald B. Disposable and cleanable filter. U. S. patent 2,918,138. Filed Feb. 13, 1957. 1 claim. Assigned to General Motors Corp. [Cl. 183-69.] An air filter for auto engines is formed from a multi-ply paper.

Maher, Edwin C. Fabricated pallet and spacer therefor. U. S. patent 2,918,241. Filed Nov. 22, 1954. 3 claims. [Cl. 248-120.] A pallet for unitizing loads of cartons or the like includes upper and lower sheets separated by plastic spacers.

Olivette, Ralph K., and Gammon, Lowell C. Pallet. U. S. patent 2,918,242. Filed Dec. 6, 1955. 3 claims. [Cl. 248-120.] A flat sheet of corrugated paperboard is used as a pallet in handling sacked goods.

Redemann, Carl T. Method and composition for producing gibberellins. U. S. patent 2,918,413. Filed Sept. 6, 1957. 3 claims. Assigned to The Dow Chemical Co. [Cl. 195-36.]

Reed, Frank L. Folding music device. U. S. patent 2,917,-965. Filed May 19, 1958. 1 claim. [Cl. 84-472.] A paper-carrying case for sheet music converts into a supporting rack and practice keyboard.

Richardson, Marguerite M. Box lid fastener. U. S. patent 2,918,319. Filed Dec. 20, 1956. 7 claims. [Cl. 292-253.] A plastic or metal device is provided as a lock for the hinged cover of a paperboard box.

Ritson, Daniel D., and Jen, Yun. Pigment starch paper coating composition containing polymethylol carbamyl polyazaalkane resins and article coated therewith. U. S. patent 2,918,438. Filed April 11, 1956. 5 claims. Assigned to American Cyanamid Co. [Cl. 260-17.3.] The composition is for paper coating.

Schneider, Samuel F. Antipopping device for still picture film projectors. U. S. patent 2,917,855. Filed April 29, 1957. 3 claims. [Cl. 40-152.] A metallic reinforcement is provided for the paperboard frame of a photo transparency.

Stremke, William F., Stremke, William F., Jr., and Pazderski, Roman R. Semi-automatic wrapping machine. U. S. patent 2,917,885. Filed Aug. 27, 1954. 18 claims. [Cl. 53-206.] A wrapper is heat-sealed about a tray containing food.

Stremke, William F., Stremke, William F., Jr., and Pazderski, Roman R. Semi-automatic wrapping machines. U. S. patent 2.917,886. Filed April 7, 1958. 21 claims. [Cl. 53-206.] This is similar to U. S. patent 2,917,885 (Dec. 22, 1959).

Thomas, Albert L., Jr., and Oglesby, Sabert, Jr. Process and apparatus for producing nonwoven sheets of fibrous materials. U. S. patent 2,917,787. Filed March 20, 1956. 3 claims. Assigned to Southern Research Inst. [Cl. 19-155.]

Winkler, Richard, and Dunnebier, Kurt. Apparatus for counting and banding envelopes and the like. U. S. patent 2,917,884. Filed Aug. 20, 1956. 9 claims. Assigned to Berkley Machine Co. [Cl. 53-198.]

Wooding, William M. Nonfibrous regenerated cellulose film containing co-resin as anchor agent. U. S. patent 2,918,386. Filed June 5, 1958. 15 claims. Assigned to American Cyanamid Co. [Cl. 117-38.]

Zachow, Henry E. Bag bundling press. U. S. patent 2,917,-881. Filed Dec. 16, 1957. 11 claims, Assigned to American Mfg. Co., Inc. [Cl. 53-124.]

Zietter, Charles R. Tamper-proof box. U. S. patent 2,918,-205. Filed June 23, 1958. 11 claims. Assigned to American Box Board Co. [Cl. 229-45.] The lid locks with the body so opening leaves visible damage.

### Dec. 29, 1959

Anderson, Swan F., and Strombeck, Leo. Wrapping machine. U. S. patent 2,918,769. Filed June 17, 1957. 30 claims. Assigned 50% to Swan F. Anderson and 50% to Ralph T. Anderson. [Cl. 53-178.] A tube is continuously formed about articles being wrapped, then it is sealed and severed between articles.

Arneson, Edwin L. Article carrier. U. S. patent 2,919,050. Filed March 5, 1957. (Divided; original filed Oct. 29, 1953.) 7 claims. Assigned to Federal Paper Board Co., Inc. [Cl. 220-113.] A six-pack bottle carrier is described.

Bell, Leo R., and Panuline, George. High speed wrapping machine. U. S. patent 2,918,772. Filed Oct. 3, 1956. 47 claims. [Cl. 53-228.] The machine wraps loaves of bread.

Camp, William M. Bobbins. U. S. patent 2,918,886. Filed April 24, 1956. 2 claims. Assigned to Coats & Clark, Inc. [Cl. 112-251.] Sewing machine bobbins are formed of paper.

Carlston, Herald L. Filing unit. U. S. patent 2,918,921. Filed May 9, 1956. 1 claim. [Cl. 129-16.1.] A marginally perforated card for use in a manual information sorting system is provided with pockets for holding film or the like.

Chandler, Frank J. Spout-type bag. U. S. patent 2,918,958. Filed March 2, 1959. 2 claims. Assigned to Paton-Chandler Process Co. [Cl. 150-9.] A kraft paper tube is used to prevent powdered material from adhering to the heat-sealable filling spout surfaces during filling of the bag.

Currivan, John F. Apparatus for loading cartons. U. S. patent 2,918,765. Filed May 1, 1957. 5 claims. Assigned to

Carton Associates, Inc. [Cl. 53-48.] The machine fills six-pack can cartons.

Daniels, Wilbert P. Carton. U. S. patent 2,919,060. Filed April 21, 1954. 4 claims. Assigned to Green Bay Box Co. [Cl. 229-51.] After tear-string opening, the carton halves may be folded back to leave the carton contents in totally exposed condition.

Hall, George, E., Jr. Papermaking process and product. U. S. patent 2,919,222. Filed Nov. 5, 1954. 5 claims. Assigned to Wyandotte Chemicals Corp. [Cl. 162-181.] A method of filling paper with hydrated calcium silicate pigment is described.

Hart, Robert T. Process for finishing coated paper. U. S. patent 2,919,205. Filed Sept. 18, 1956. 13 claims. Assigned to S. D. Warren Co. [Cl. 117-64.] A cast-coating process is described.

Krupp, Robert F., and Wagner, Jan K. Container case feeding and opening means. U. S. patent 2,918,773. Filed May 29, 1958. 14 claims. Assigned to Gerber Products Co. [Cl. 53-382.] The top flaps of a case holding cans or jars are opened and the case fed to a machine for unloading them.

Labino, Dominick. Method for making glass paper. U. S. patent 2,919,221. Filed Jan. 13, 1956. 6 claims. Assigned to L-O-F Glass Fibers Co. [Cl. 162-156.]

Lidgard, Edward J. Container for a plurality of sheets of glass or the like. U. S. patent 2,918,022. Filed Oct. 3, 1957. 15 claims. Assigned to Flotepak Corp. [Cl. 206-62.] Laminated corrugated paperboard elements are used as interior packing.

McCleary, Harry R. Dispenser carton. U. S. patent 2,919,-020. Filed June 24, 1957. 6 claims. Assigned to Thormac Packaging Corp. [Cl. 206-57.] A flat carton holds and dispenses a stack of sheet material.

Malmquist, Alfred B. Coated book cover material. U. S. patent 2,919,206. Filed March 21, 1957. 1 claim. Assigned to E. I. du Pont de Nemours & Co. [Cl. 117-76.] Various resin coatings are applied to paper and textiles.

Monroe, Wilfred E., and Cooper, William F. Press unloading apparatus. U. S. patent 2,918,862. Filed Oct. 30, 1956. 3 claims. Assigned to International Paper Co. [Cl. 100-198.] Multiple opening hot-presses for wood-particle board and the like are unloaded.

Munton, John P., and Peterson, Philip A. End dike for a paper coating machine. U. S. patent 2,918,899. Filed Nov. 4, 1958. 4 claims. Assigned to Rice Barton Corp. [Cl. 118-413.]

Northrup, Willard F. Pressure-sensitive tape dispenser and applier. U. S. patent 2,919,044. Filed April 18, 1957. 7 claims. Assigned to International Business Machines Corp. [Cl. 216-29.]

Printz, Warren G. Auto-tension felt stretcher. U. S. patent 2,918,970. Filed March 10, 1958. 14 claims. Assigned to The Manchester Machine Co. [Cl. 162-273.]

Rado, Leopold. Method and means for the production of liquid or paste filled containers. U. S. patent 2,918,768. Filed Nov. 14, 1955. 7 claims. [Cl. 53-178.] Material is filled into a tube, the tube is sealed to form a primary container, and this container is then sealed so as to create a number of smaller containers within the primary container.

Reinhardt, Charles M. Process for the manufacture of globular nitrocellulose. U. S. patent 2,919,181. Filed Jan. 12, 1955. 4 claims. Assigned to Olin Mathieson Chemical Corp. [Cl. 52-22.]

Rogier, Clarence F. Roll handling machine. U. S. patent 2,918,766. Filed March 19, 1952. 24 claims. Assigned to Johnson Fare Box Co. [Cl. 53-74.] A machine for wrapping rolls of coins is provided with means to receive the wrapped packs and print, count, and stack them.

Searle, Ronald W. Log debarking machines having universally mounted and inwardly biased cutters. U. S. patent 2,918,952. Filed June 9, 1958. 1 claim. [Cl. 144-208.]

Thumm, Byron A. Producing all skin rayon. U. S. patent 2,919,203. Filed Dec. 5, 1955. 3 claims. Assigned to American Viscose Corp. [Cl. 106-165.] The coagulation modifier is an alkylene oxide adduct of $\beta$-aminoethyl morpholine.

Wickliff, Lee R. Packaging apparatus. U. S. patent 2,918,771. Filed Aug. 23, 1954. 5 claims. Assigned to Armour and Co. [Cl. 53-189.] The machine described fills bags with poultry giblets.

Zernov, Peter. Apparatus for decurling a web. U. S. patent 2,918,897. Filed July 28, 1958. 3 claims. Assigned to Mercury Engineering Corp. [Cl. 118-124.] An apparatus is provided for decurling a waxed or printed paper web without defacing the coating.

The following patents were received later than those of the same issue date and have accumulated during the past quarter.

### Jan. 20, 1959

Schoenauer, Wolfgang. Pigment dyestuffs of the anthraquinone series. U. S. patent 2,870,172. Filed Nov. 13, 1956. 7 claims. Assigned to Sandoz A.G. [Cl. 260-368.] These are of use in coloring paper.

### April 7, 1959

Schulenburg, Wilhelm. Fire retardant composition and method of coating therewith. U. S. patent 2,881,088. Filed March 22, 1956. 9 claims. Assigned to Alim Corp. [Cl. 117-33.] The coating composition may be applied to wallboard.

### May 5, 1959

Kress, Bernard H. Water-soluble acetals of glutaraldehyde and method of making same. U. S. patent 2,885,443. Filed April 9, 1956. 4 claims. Assigned to Quaker Chemical Prods. Corp. [Cl. 260-615.] These are of use in imparting wet-strength and dimensional stability to paper.

### May 19, 1959

Tolkmith, Henry, Blair, Etcyl H., Kauer, Kenneth C., and Britton, Edgar C. Method for the manufacture of *O*-aryl *O*-lower alkyl phosphorochloridothioates. U. S. patent 2,887,506. Filed Oct. 24, 1957. 6 claims. Assigned to The Dow Chemical Co. [Cl. 260-461.] The compounds are of use in preserving paper.

### June 23, 1959

Boettner, Fred E. Method for the preparation of substituted sorbitylureas. U. S. patent 2,891,944. Filed March 20, 1957. 10 claims. Assigned to Rohm & Haas Co. [Cl. 260-211.] The sorbitylureas may be used in wet-strengthening paper.

### July 7, 1959

Opderbeck, Fritz. Method for producing alcohol from waste sulfite cellulose liquors. U. S. patent 2,893,919. Filed Aug. 23, 1955. 7 claims. Assigned to Phrix-Werke A.G. [Cl. 195-39.]

### July 14, 1959

Irthum, Harold J., and Schorken, Frederick L. Sealing means for rotary drum filters. U. S. patent 2,894,635. Filed July 23, 1956. 1 claim. Assigned to Dorr-Oliver, Inc. [Cl. 210-402.]

### July 28, 1959

Eitel, Kurt, Schmidt, Fritz, and Mauthe, Gustav. Process for the preparation of coating of soft resins from polyisocyanates and compounds containing hydroxyl groups. U. S. patent 2,897,166. Filed Nov. 5, 1954. 6 claims. Assigned 50% to Farbenfabriken Bayer A.G. and 50% to Mobay Chemical Co. [Cl. 260-22.] The composition may be used for coating paper.

Töppel, Otmar. Method for the separation of carbonyl compounds. U. S. patent 2,897,238. Filed Aug. 18, 1955. 13 claims. Assigned to Aschaffenburger Zellstoffwerke A.G. [Cl. 260-600.] The method described may be applied in the pulp industry for making furfural, vanillin, etc.

### Aug. 11, 1959

Berndt, Franz, and Wendlandt, Hans-Georg. Process for purifying air. U. S. patent 2,899,267. Filed March 23, 1956. 2 claims. Assigned to Spinnfaser A.-G. [Cl. 23-4.] Hydrogen sulfide is removed from air effluent from the viscose process.

### Aug. 18, 1959

Suen, Tzeng J., and Jen, Yun. Resinous compositions. U. S. patent 2,900,367. Filed Dec. 31, 1956. 12 claims. Assigned to American Cyanamid Co. [Cl. 260-67.6.] Wet-strength agents for paper comprise thermosetting aldehyde condensates of diguanamines.

Tien, Jack M. Acyl hydrazine derivatives of bis(4-dimethylaminophenyl) methane and process. U. S. patent 2,900,388. Filed Aug. 8, 1957. 28 claims. [Cl. 260-295.] The hydrazines are used as coloring materials in making carbon paper and other duplicating papers.

### Aug. 25, 1959

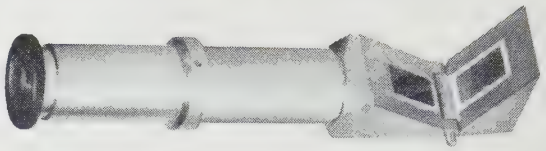
Chance, Leon H., Drake, George L., Jr., and Reeves, Wilson A. Polymers made from 1-aziridinyl phosphine oxides and sulfides and flame resistant organic textiles. U. S. patent 2,901,444. Filed June 5, 1956. 4 claims. Assigned to The United States of America. [Cl. 260-2.] Paper may also be treated.

Jordan, Arthur D., Jr. Aqueous composition comprising ammonium salt of maleamic acid/diisobutylene copolymer and linear addition polymer and article coated therewith. U. S. patent 2,901,453. Filed Jan. 14, 1957. 11 claims. Assigned to Rohm & Haas Co. [Cl. 260-29.6.] The composition may be used in coating paper.

Shannon, Richard F., and Mitchell, Robert H. High tempera-

. . . for Starch, Sizings and other Solutions

POCKET REFRACTOMETER



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ture resistant vitreous material. U. S. patent 2,901,379. Filed April 9, 1956. 17 claims. Assigned to Owens-Corning Fiberglas Corp. [Cl. 117-124.] The fibers of glass paper are coated with a refractory metal oxide.

**Sept. 8, 1959**

Crane, Walton B. Paperboard shipping crate and interlocked crate unit. U. S. patent 2,903,176. Filed May 17, 1956. 10 claims. Assigned to Allied Plastics Co. [Cl. 229-27.] A paperboard produce shipper is provided with means to interlock the boxes when they are stacked.

Murata, Kwanji. Sulfur dioxide-acetic acid reaction product. U. S. patent 2,903,481. Filed Nov. 26, 1956. 2 claims. [Cl. 260-545.] The product is used as a catalyst in the esterification of cellulose.

**Sept. 15, 1959**

Sakornbut, Songe S. Preservative composition comprising tetraalkali metal pyrophosphate, a polychlorophenate and a heavy metal salt. U. S. patent 2,904,466. Filed Sept. 6, 1956. 14 claims. Assigned to Monsanto Chemical Co. [Cl. 167-38.5.] The composition may be used to render paper resistant to insects, fungi, etc.

**Sept. 29, 1959**

Thomann, Erwin. Bituminous roadmaking material. U. S. patent 2,906,633. Filed July 24, 1956. 1 claim. Assigned to A. G. Balmholz Steinbrüche & Hartschotterwerke. [Cl. 106-82.] Tall oil is used.

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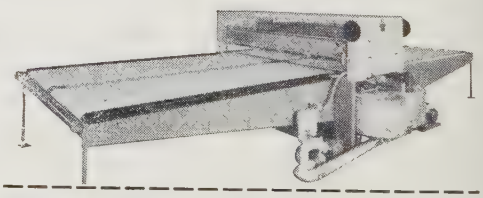

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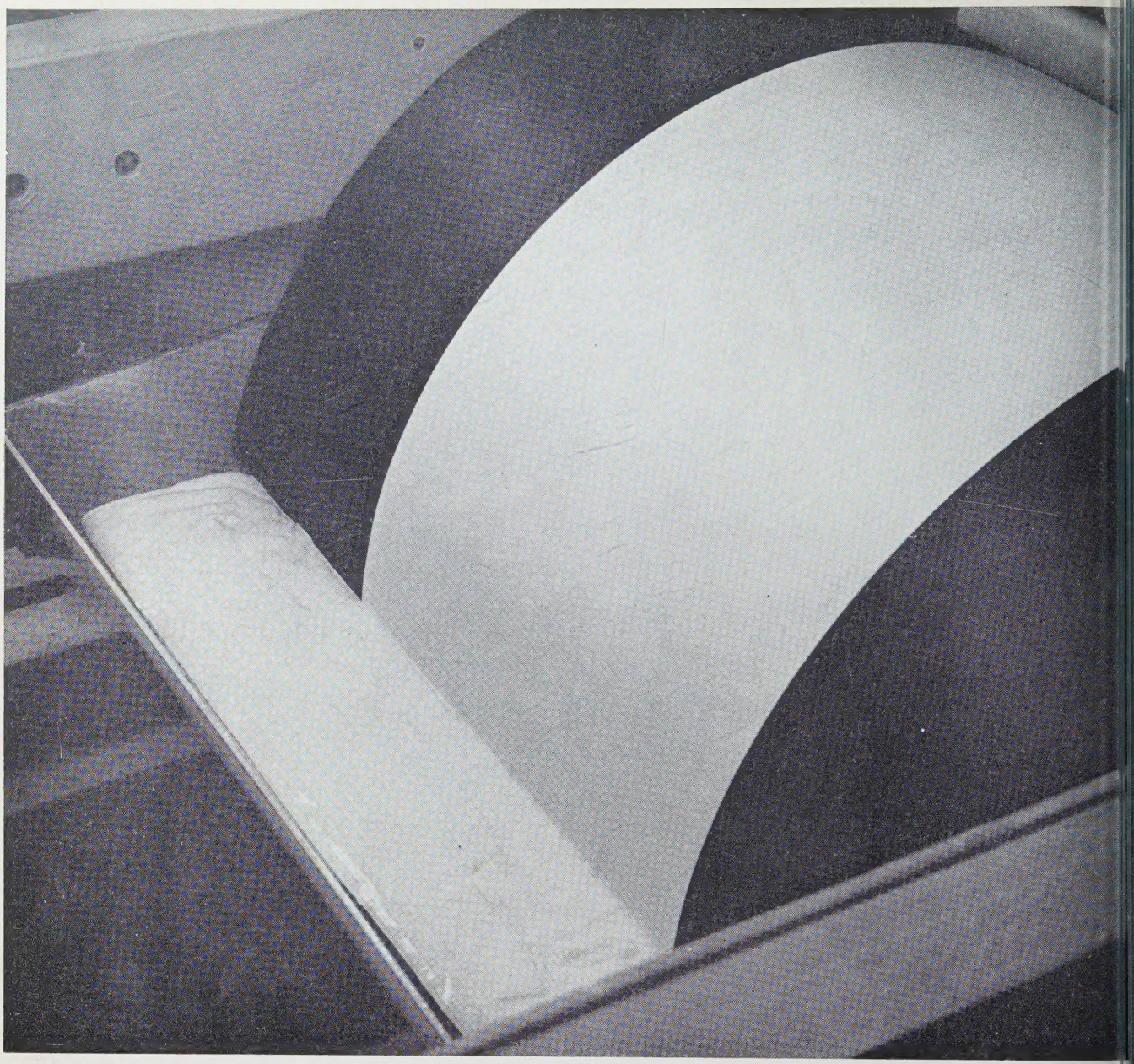

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